NEW FIELD AND MODELING RESULTS FROM A SIMULATED WASTE PIT USING THE ENHANCED VERY EARLY TIME ELECTROMAGNETIC (VETEM) PROTOTYPE SYSTEM

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Outline

- Why VETEM ?
- What’s VETEM ?
- What’s new in VETEM ?
- The Cold Test Pit & VETEM.
- Modeling for VETEM.
- Quo Vadis VETEM ?
- Conclusions and Acknowledgements.

Why VETEM ?

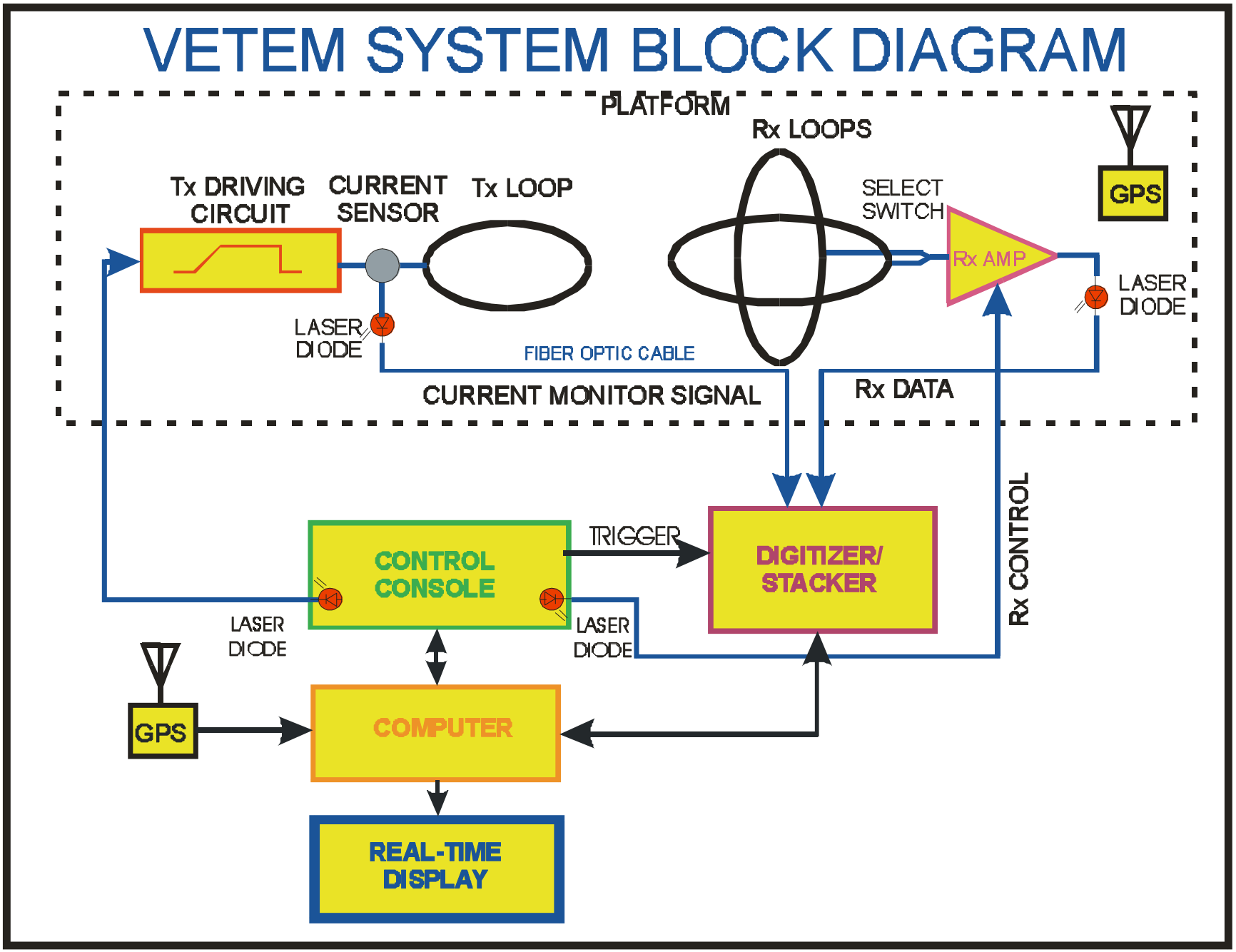
- Better penetration than GPR through conductive earth -- typical of clay caps over waste pits.
- Better resolution in first 5 meters than time-domain EM systems.

What's VETEM ?

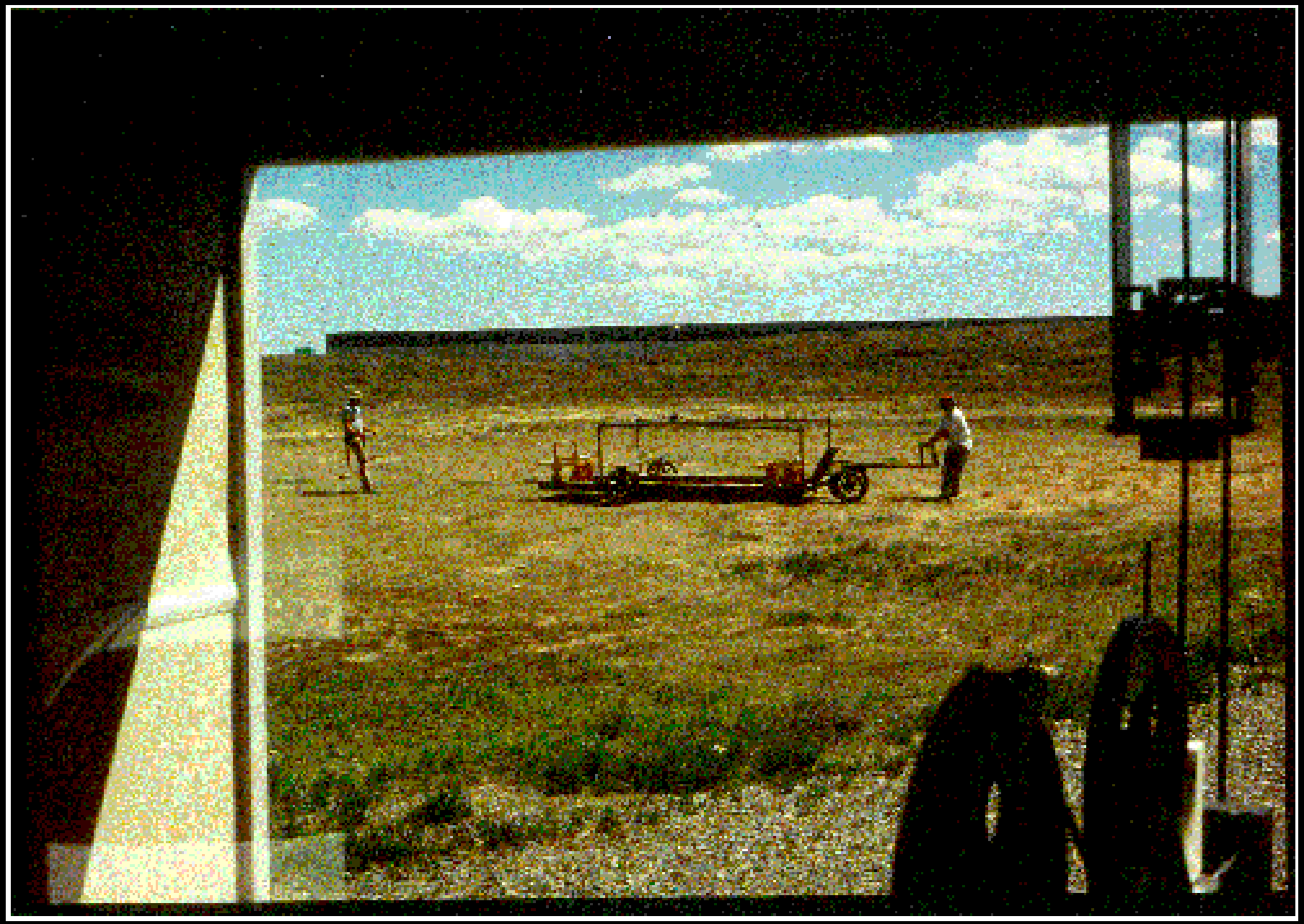
- A time-domain EM system with fast Tx turn-off (or can function as low freq. GPR)
- Typically record entire waveform.
- Real-time digitizing, stacking & display
- Continuous profiling while moving
- Flexible
  - Can use electric field dipoles
  - Can use magnetic field loops

Comments on System Block Diagram

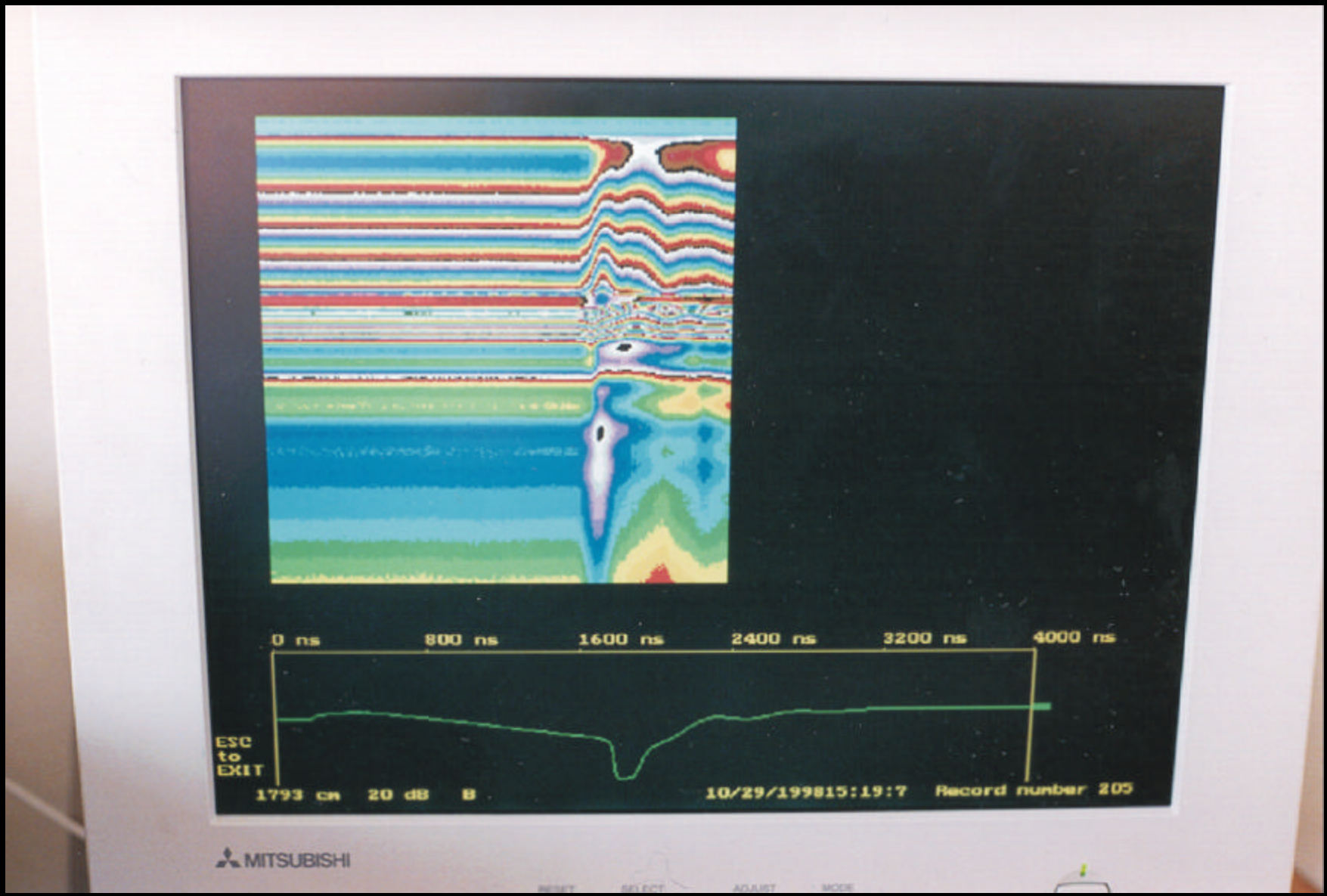
- Everything inside dotted box is on remote cart and is battery powered.
- All data and control lines to/from cart are fiber-optic to avoid unwanted EM coupling.
- Real-time digitizer/stacker is unique in system of this type. No sampling is done prior to digitizing. Allows capture and averaging of every waveform.
- Advantage is fast signal-to-noise improvement through waveform averaging.
- Typical operating speed is 10 to 25 cm/s (20 to 50 ft/min).
- Cart currently towed with borehole radar winch. Will develop all-terrain vehicle towed version.


VETEM SYSTEM BLOCK DIAGRAM
PLATFORM
Rx LOOPS
Tx DRIVING CIRCUIT
CURRENT SENSOR
Tx LOOP
SELECT SWITCH
GPS
Rx AMP
LASER DIODE
LASER DIODE
FIBER OPTIC CABLE
CURRENT MONITOR SIGNAL
Rx DATA
Rx CONTROL
TRIGGER
CONTROL CONSOLE
DIGITIZER/ STACKER
LASER DIODE
LASER DIODE
GPS
COMPUTER
REAL-TIME DISPLAY

Borehole Radar Drawworks



Real-Time Data Display



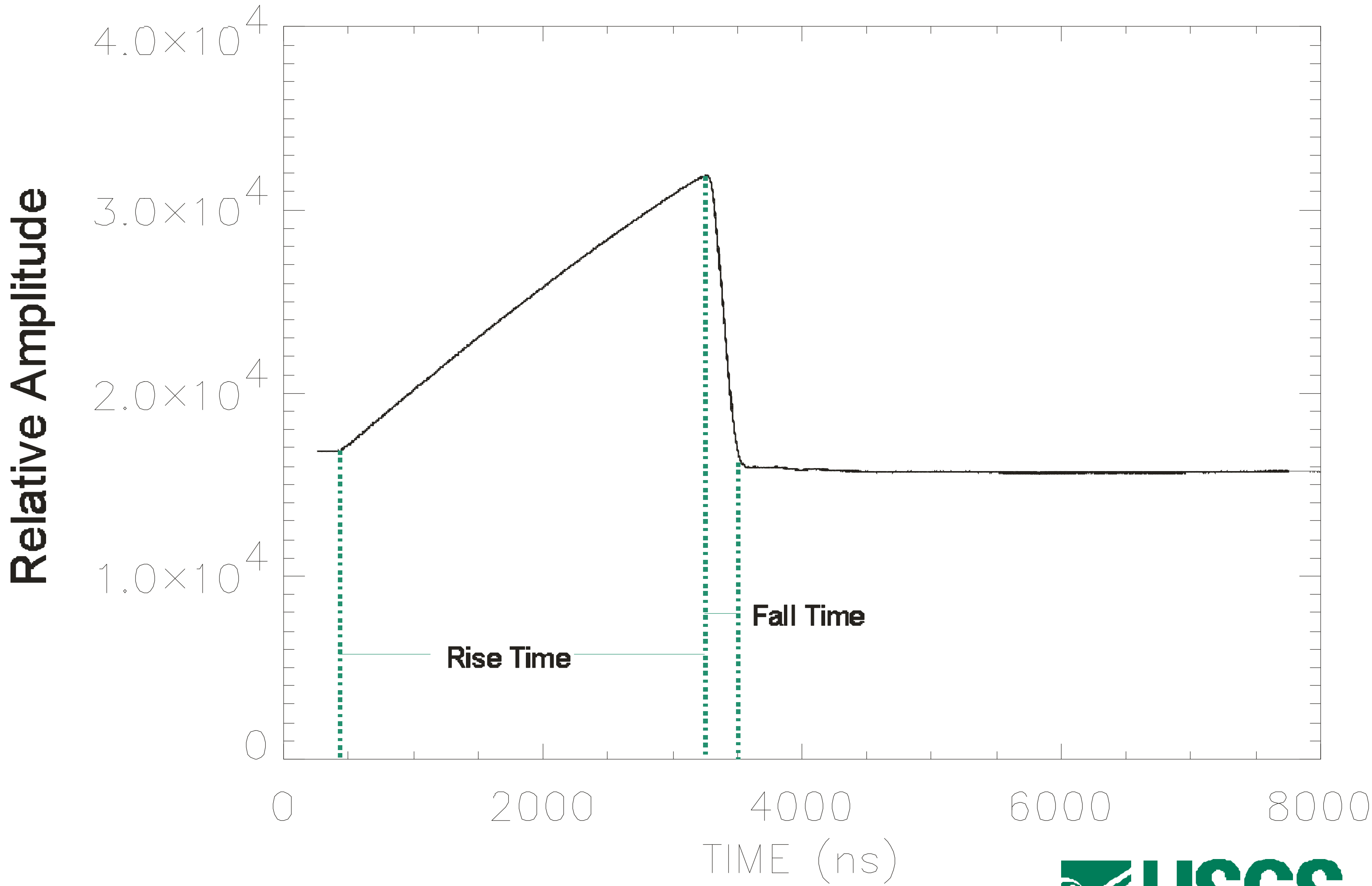
What's new in VETEM ?

- Two new transmitters - faster and slower
- 30 times greater Tx current
- 10 times larger area loop antennas
- Overlapped antenna configuration
- New cart for greater antenna spacing
- GPS receivers
- New data processing and visualization
- New 3-D forward model

Higher current output transmitter

- Ramps current up approximately linearly at about 6 Amperes/microsecond.
- Can drive 30 Amperes peak current into new Tx antennas.
- Pulse width controlled by software.
- 10 kHz repetition rate.
- Turn-off ramp about 60 Amps/microsecond.

Transmitted Waveform

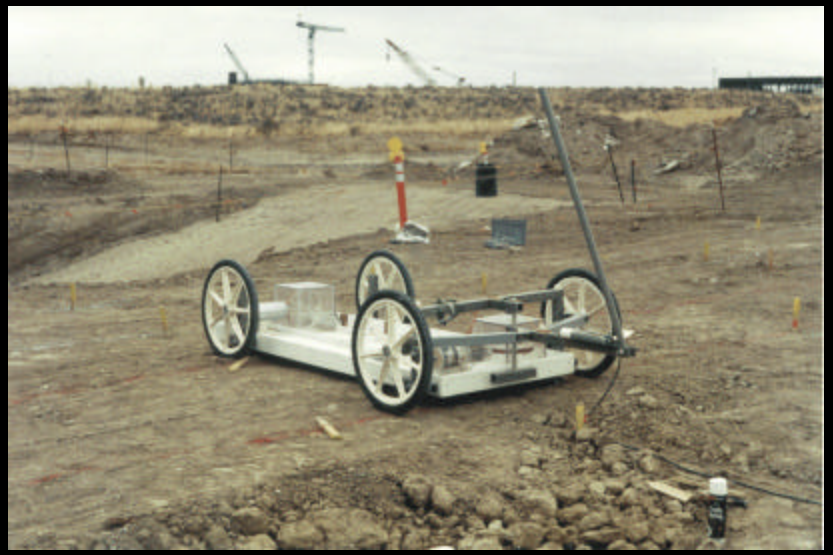


File:p7_5smoi.L01

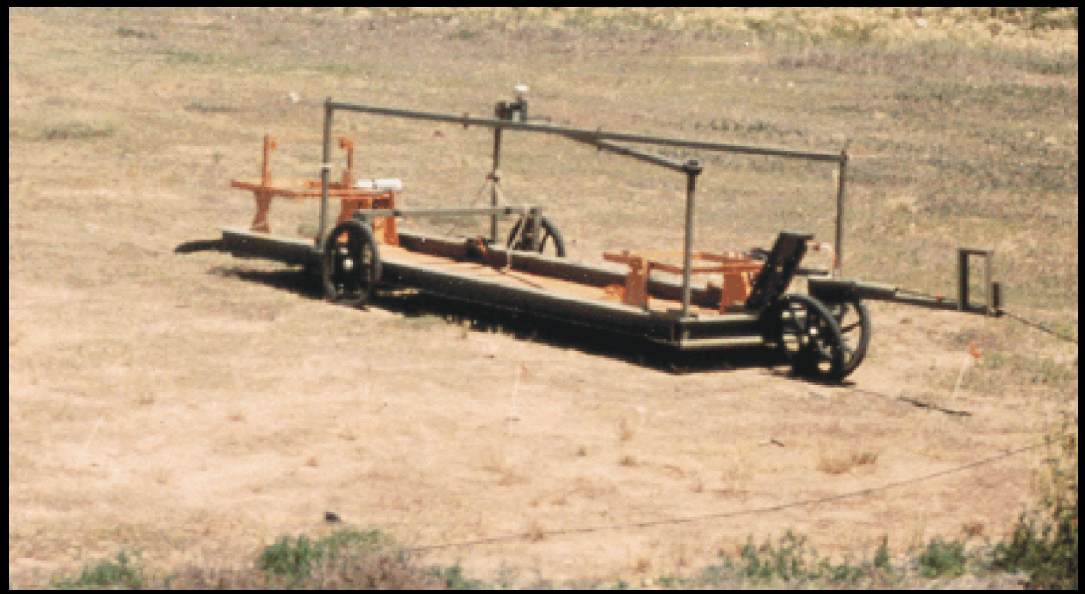
Comments on carts and antennas

- The original cart allowed antenna spacing to 2 meters maximum. Metal almost totally eliminated in both carts.
- New cart up to 4 m antenna spacing for greater depth.
- New cart more rigid and has 3-point suspension to avoid antenna misalignment due to twisting of cart.
- Original loop antennas still available and very good for shallow applications, but newer antennas have greater area and therefore greater signal levels for deeper applications.
- Electric field antennas under development. These should prove superior for shallow response to dielectric permittivity changes (e.g. liquid spills).

Original Cart



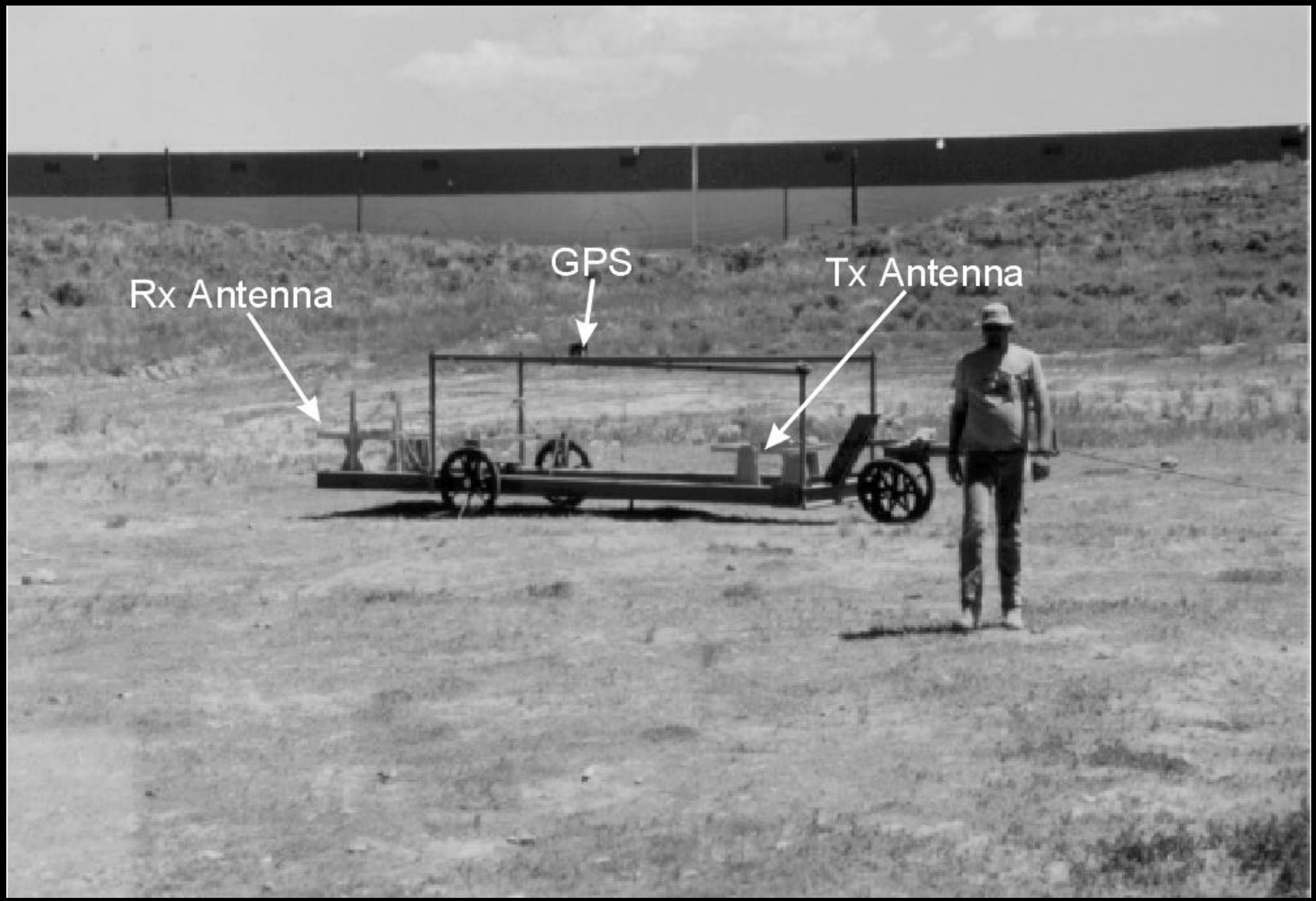
New Cart



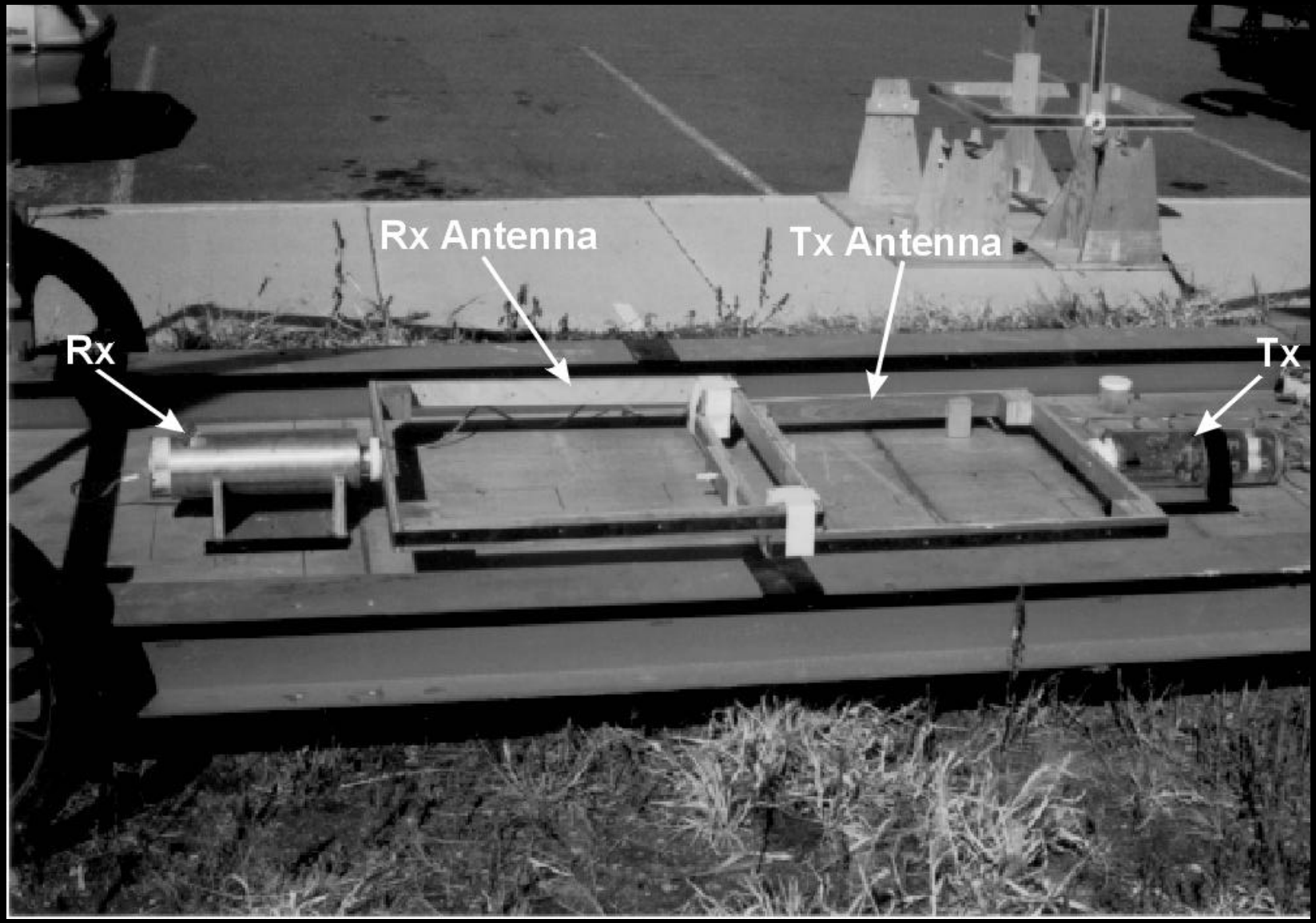
Objectives for different antenna configurations

- Perpendicular loop antennas null the response to the primary field -- the field that the transmitting antenna would produce in free space. This configuration retains response to earth electrical properties.
- Overlapped loop antennas can approximately null both the primary field and local average earth response by adjusting the Rx and Tx antenna overlap. This maximizes the system response to EM changes due to buried objects or changes in earth parameters. This procedure minimizes the dynamic range requirement on the receiver. Very small changes in antenna overlap cause large changes in signal. Must be readjusted for local site earth conductivity.
- Coplanar loop antennas at short spacing saturate receiver due to the maximally coupled primary field. Requires extremely high dynamic range in receiver or giving up early time part of waveform.
- We are investigating gradiometer configurations.

Large antennas at 4 m spacing



Overlapped Antennas

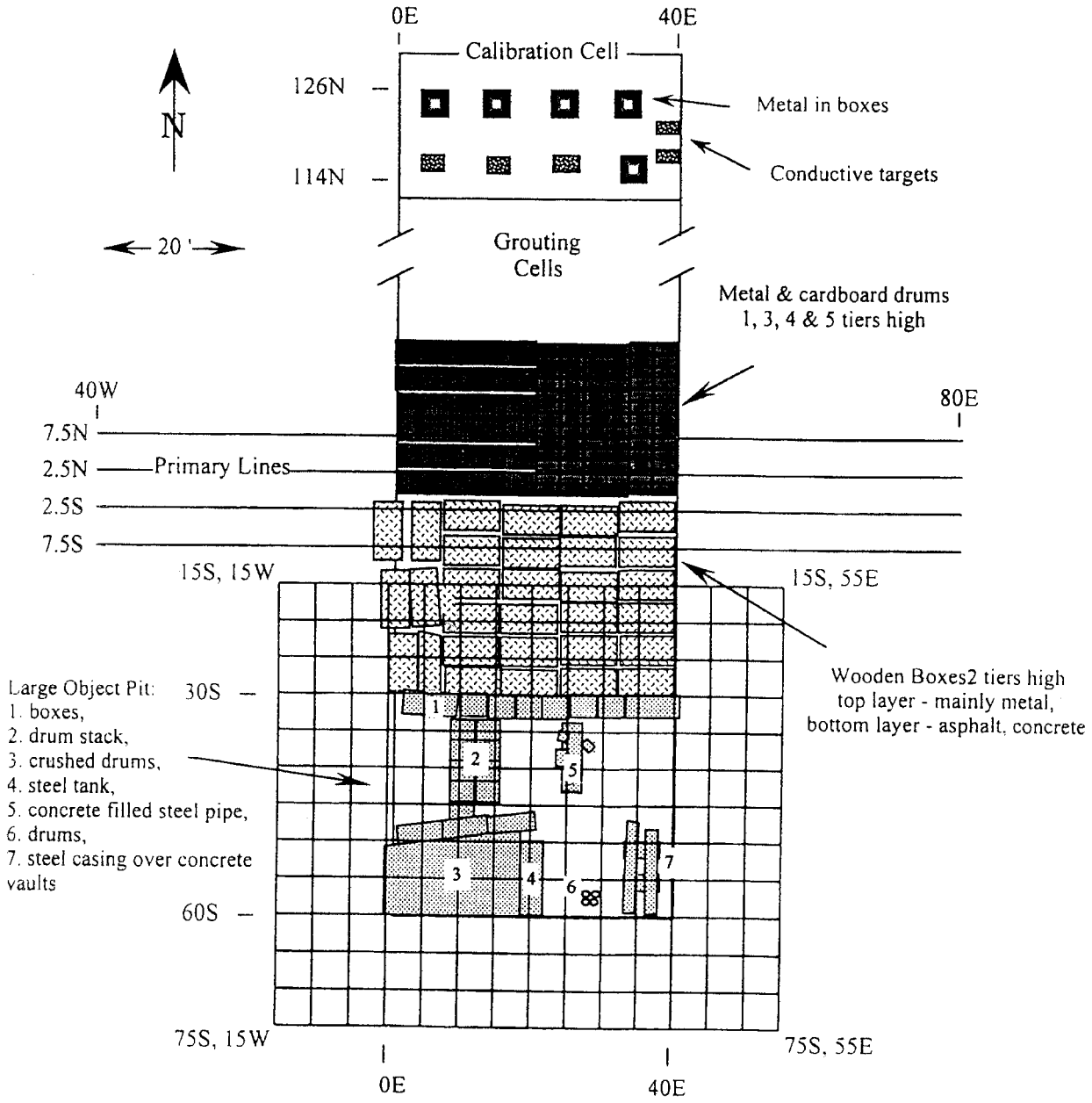


The Cold Test Pit at INEEL

Cold Test Pit Objectives

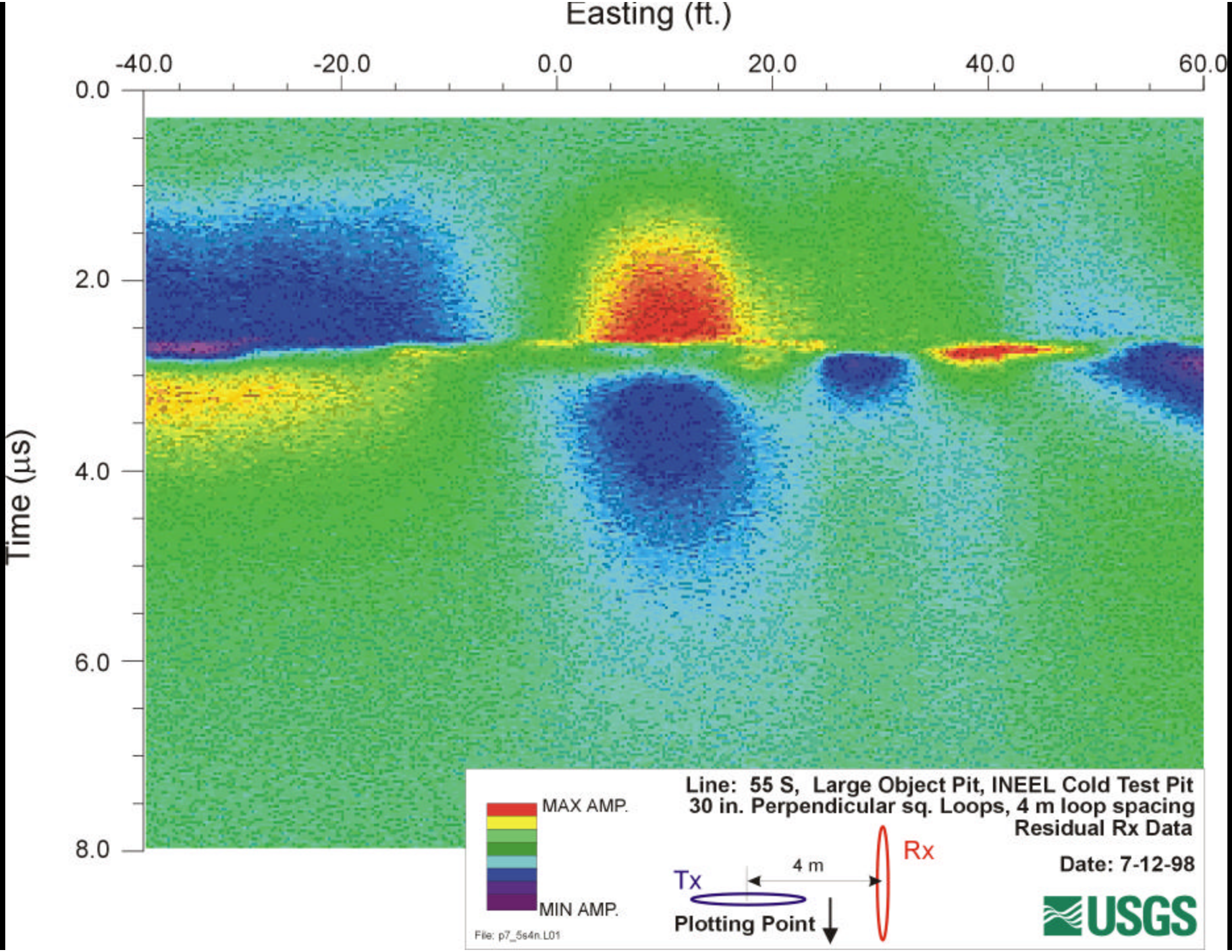
- "Cold" here means non-radioactive.
- In all other respects the CTP is intended to simulate physical characteristics typical of actual waste pits at the Idaho National Environmental and Engineering Laboratory.
- Several different portions of the CTP.
- We show results from the Large Object Pit and Calibration Cell portions of the CTP.

INEEL COLD TEST PIT (CTP)

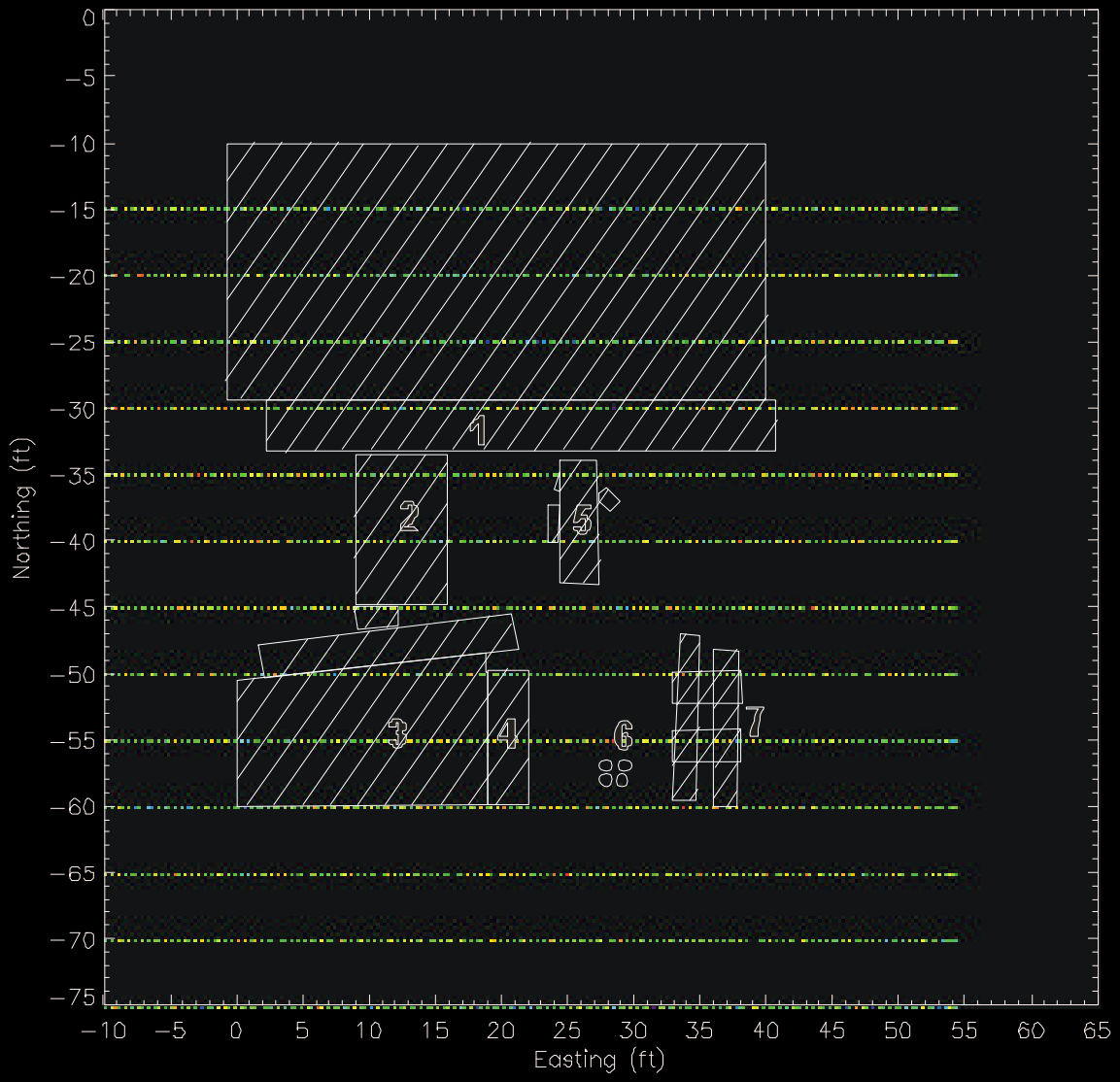


Line 55S profile data & Targets 3,4,7 (compare previous map and next slide)

- Target 3 (crushed drums) appears in appropriate location (about 0E to 20E). Large response indicates drums must be metal, not cardboard.
- Target 4 (steel tank) response difficult to distinguish from adjacent target 3 in this data set.
- The average Rx waveform has been removed to produce a “residual” data profile which is shown here.
- Response to metal objects changes polarity before and after Tx turnoff (e.g. red to blue or purple). Tx turnoff at about 2.7 microseconds in this data set.
- Response to Target 7 (two steel casings) is more complex. The peak positive and negative responses are not directly over the casings and the apparent location of the targets shifts laterally with time. See later modeling results for further discussion.

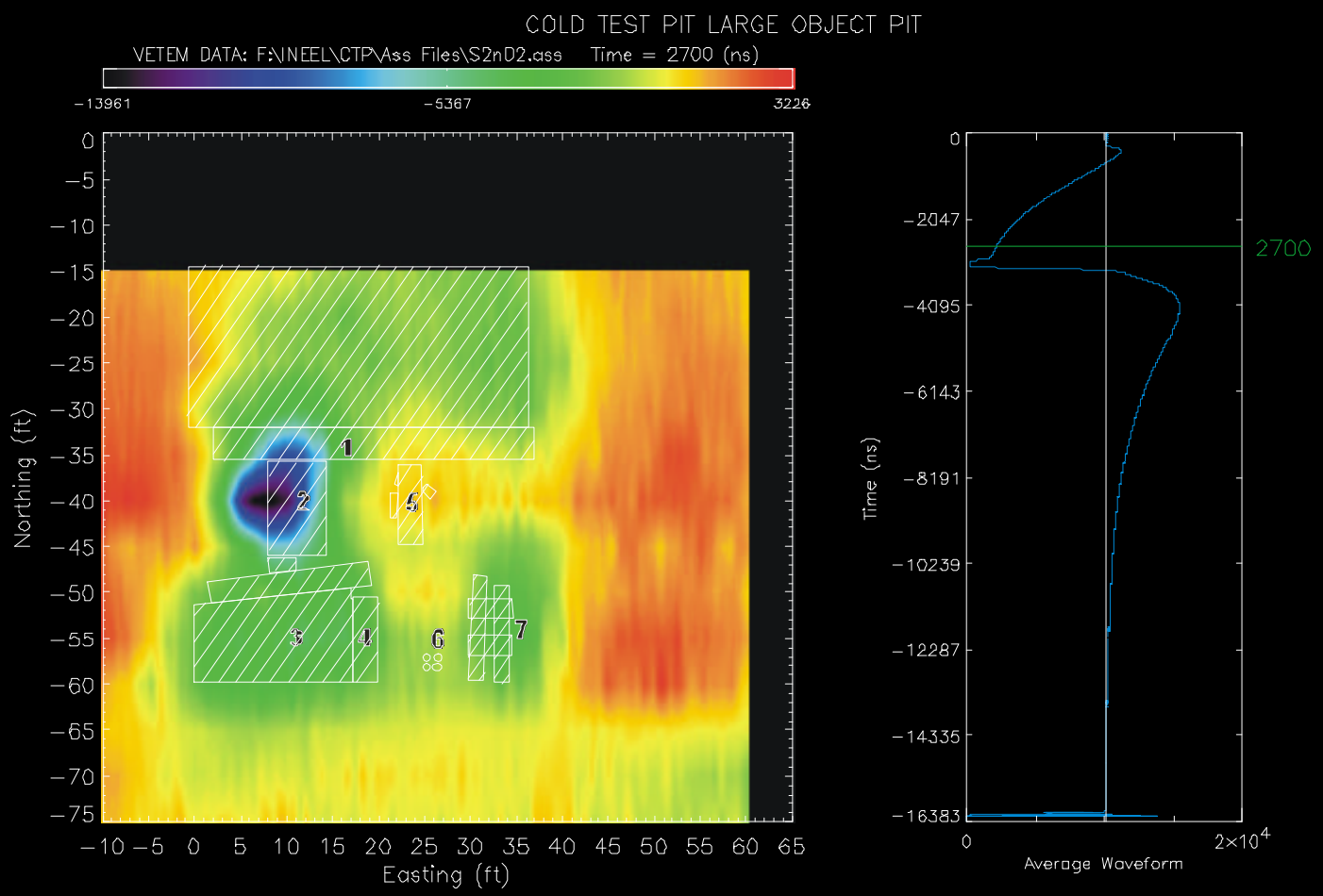

Easting (ft.)
-40.0
-20.0
0.0
20.0
40.0
60.0
Time (µs)
0.0
2.0
4.0
6.0
8.0
MAX AMP.
MIN AMP.
File: p7_5s4n.L01
Line: 55 S, Large Object Pit, INEEL Cold Test Pit
30 in. Perpendicular sq. Loops, 4 m loop spacing
Residual Rx Data
Date: 7-12-98
Tx
4 m
Rx
Plotting Point
USGS

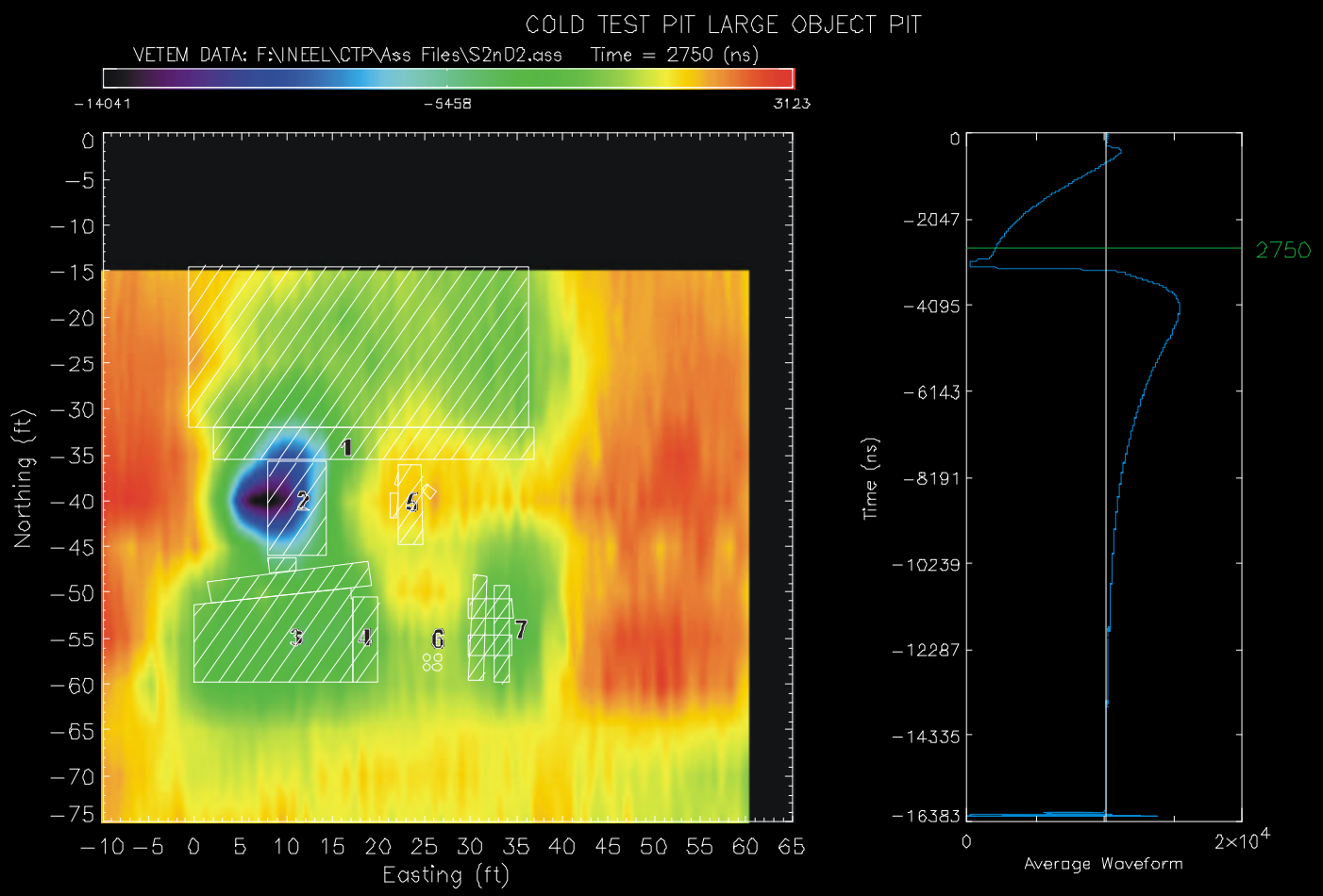
COLD TEST PIT
LARGE OBJECT PIT
TRAVERSE LINES

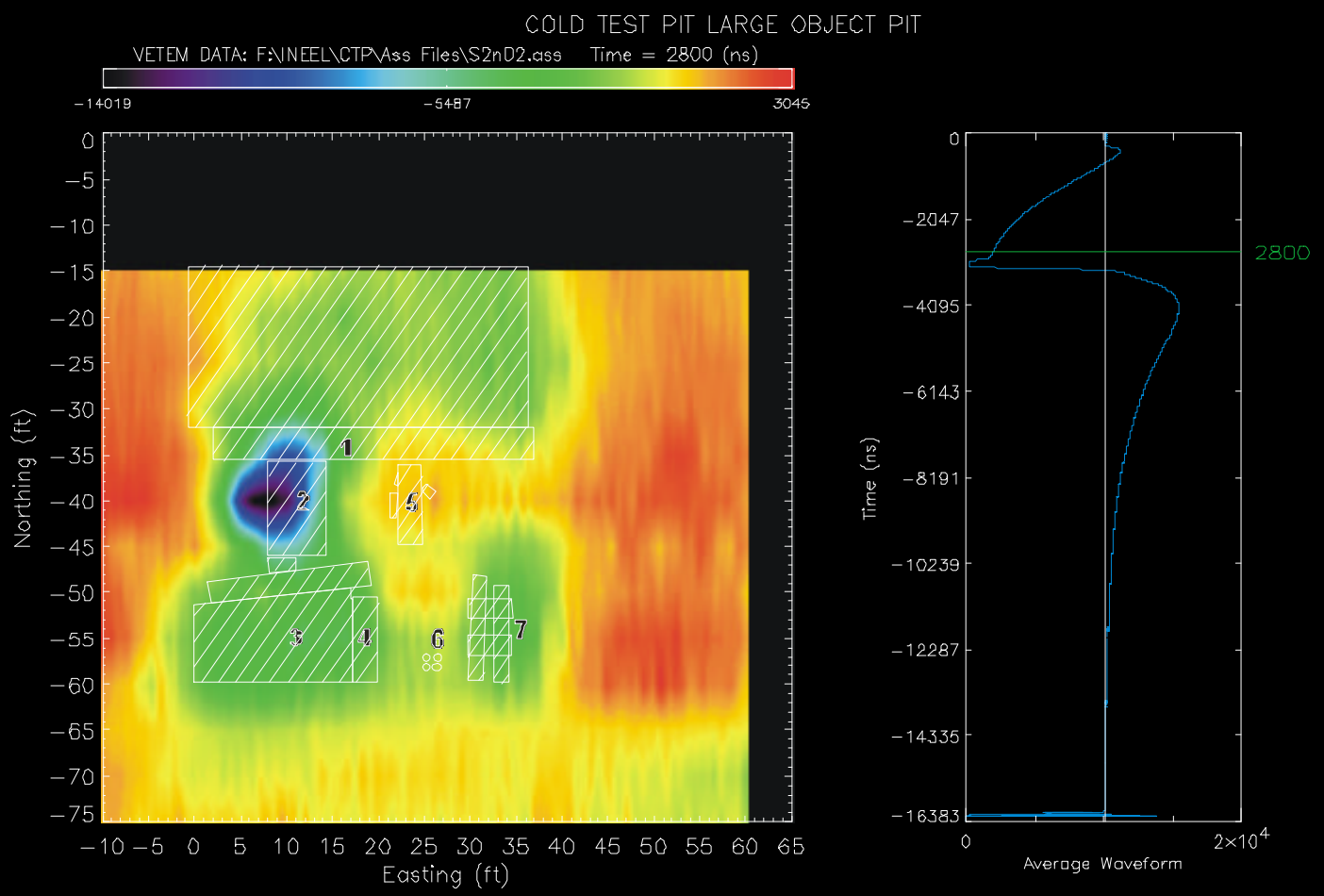


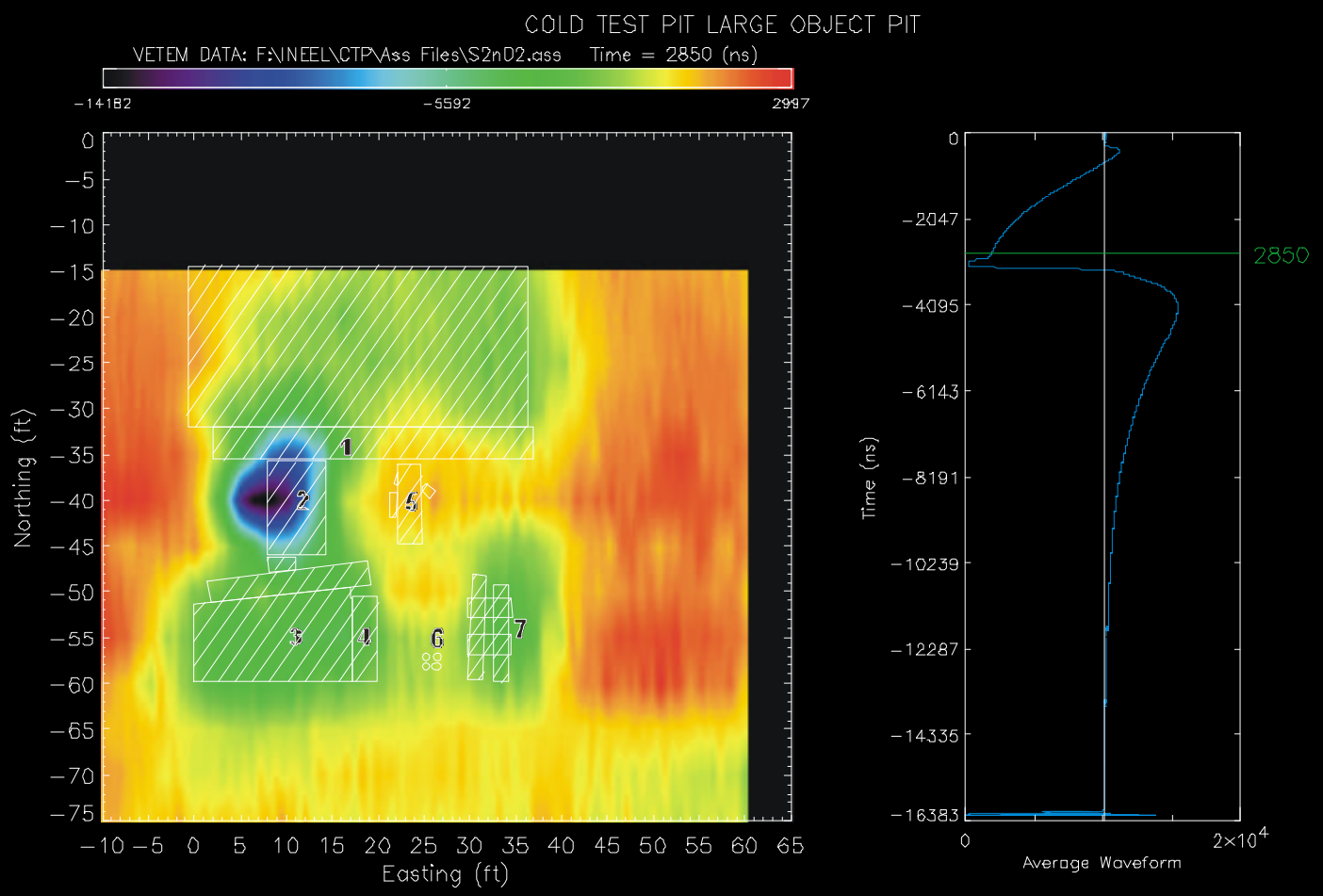
Comments on time-slice displays

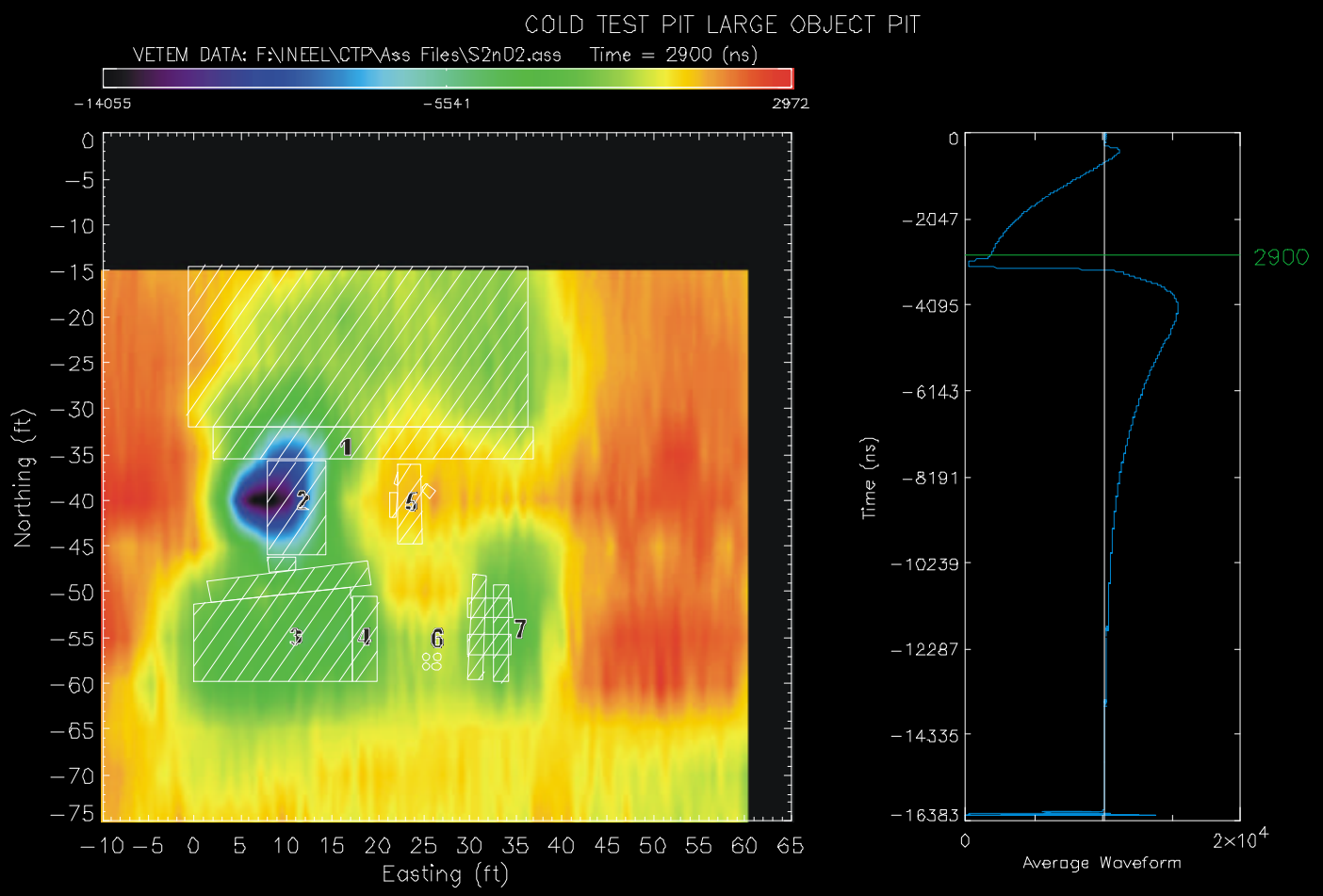
- Used perpendicular antennas at 2-m spacing (shown) and overlapped.
- Time slices begin when Tx on. Colors reverse after Tx off.
- Waveform on right is an average, but time-slices are of residual data.
- The horizontal line at right shows time of display.
- Color scales have been manually adjusted.
- Numbers on color bar indicate total range of data in digitizer units.
- Signal-to-noise ratio O.K. to about 10000 ns without smoothing data.
- Strongest response is from target 2 (drum stack). Apparent maximum response is shifted slightly to the west from that indicated on map. See later discussion of modeling results.
- Note also that the apparent position of Target 7 wanders. See modeling results and compare with previous profile of line 55S.


COLD TEST PIT LARGE OBJECT PIT
VETEM DATA: F:\INEEL\CTP\Ass Files\S2n02.ass Time = 2700 (ns)
-13961
-5367
3226
Northing (ft)
Easting (ft)
1
2
3
4
5
6
7
Time (ns)
2700
Average Waveform
2x10^4


COLD TEST PIT LARGE OBJECT PIT
VETEM DATA: F:\INEEL\CTP\Ass Files\S2n02.ass Time = 2750 (ns)
-14041
-5458
3123
Northing (ft)
Easting (ft)
1
2
3
4
5
6
7
Time (ns)
2750
Average Waveform
2x10^4


COLD TEST PIT LARGE OBJECT PIT
VETEM DATA: F:\INEEL\CTP\Ass Files\S2n02.ass Time = 2800 (ns)
-14019
-5487
3045
Northing (ft)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
-65
-70
-75
-10 -5 0 5 10 15 20 25 30 35 40 45 50 55 60 65
Easting (ft)
1
2
3
4
5
6
7
Time (ns)
0
-2047
-4095
-6143
-8191
-10239
-12287
-14335
-16383
2800
0
2x10^4
Average Waveform


COLD TEST PIT LARGE OBJECT PIT
VETEM DATA: F:\INEEL\CTP\Ass Files\S2n02.ass Time = 2850 (ns)
-14182
-5592
2997
Northing (ft)
Easting (ft)
1
2
3
4
5
6
7
Time (ns)
2850
Average Waveform
2×10^4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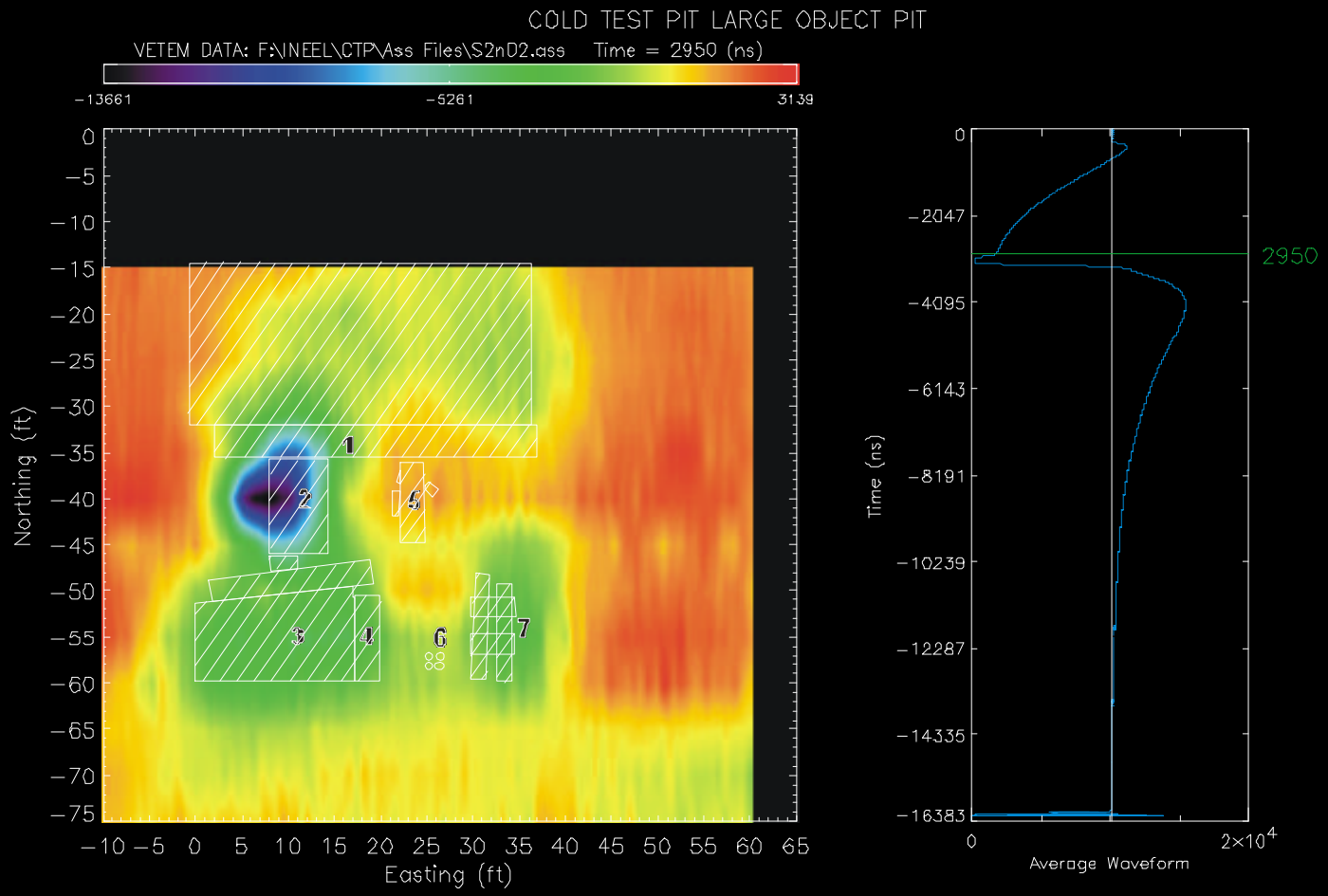
-14055
-5541
2972
Northing (ft)
Easting (ft)
1
2
3
4
5
6
7
Time (ns)
2900
Average Waveform
2×10^4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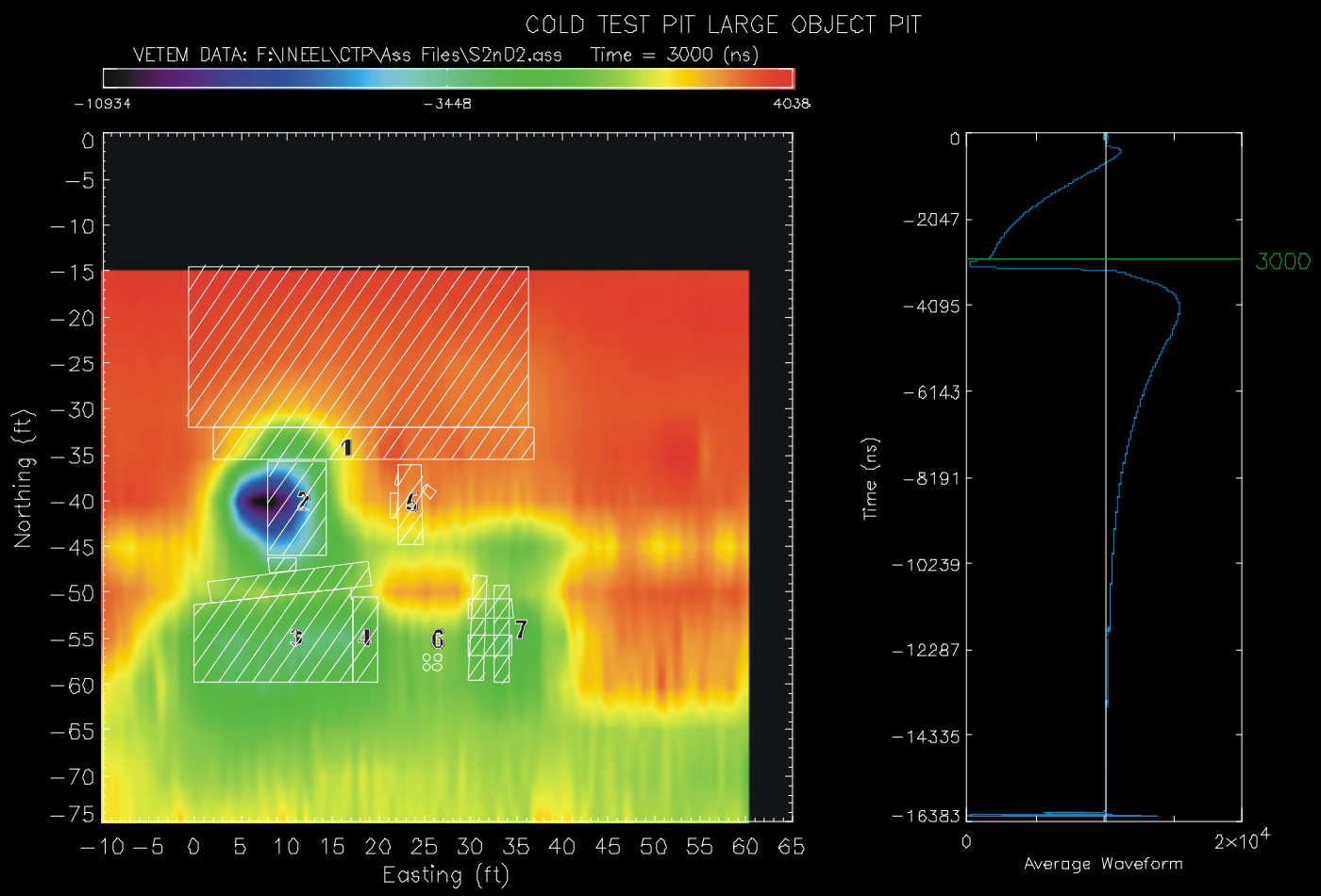
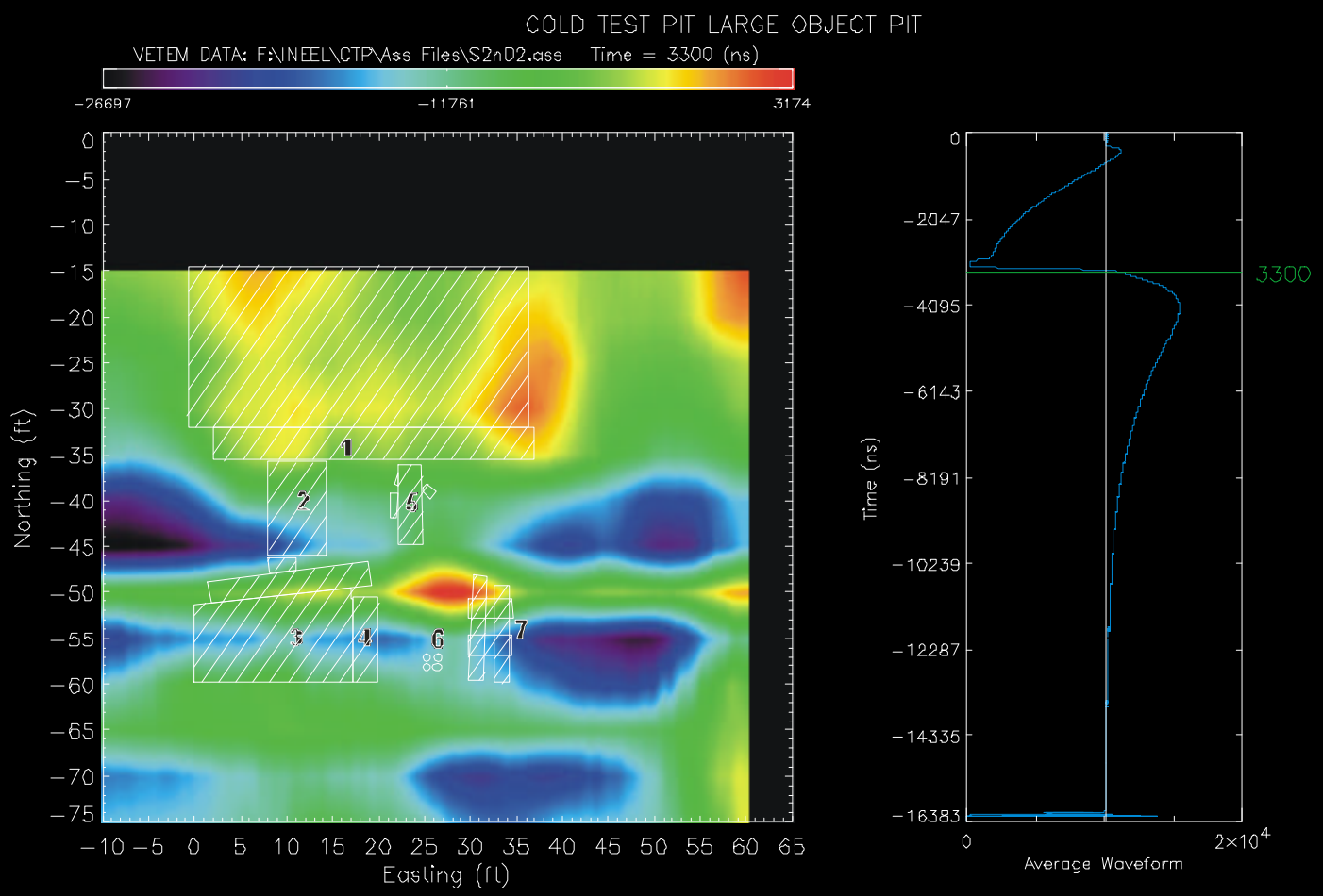
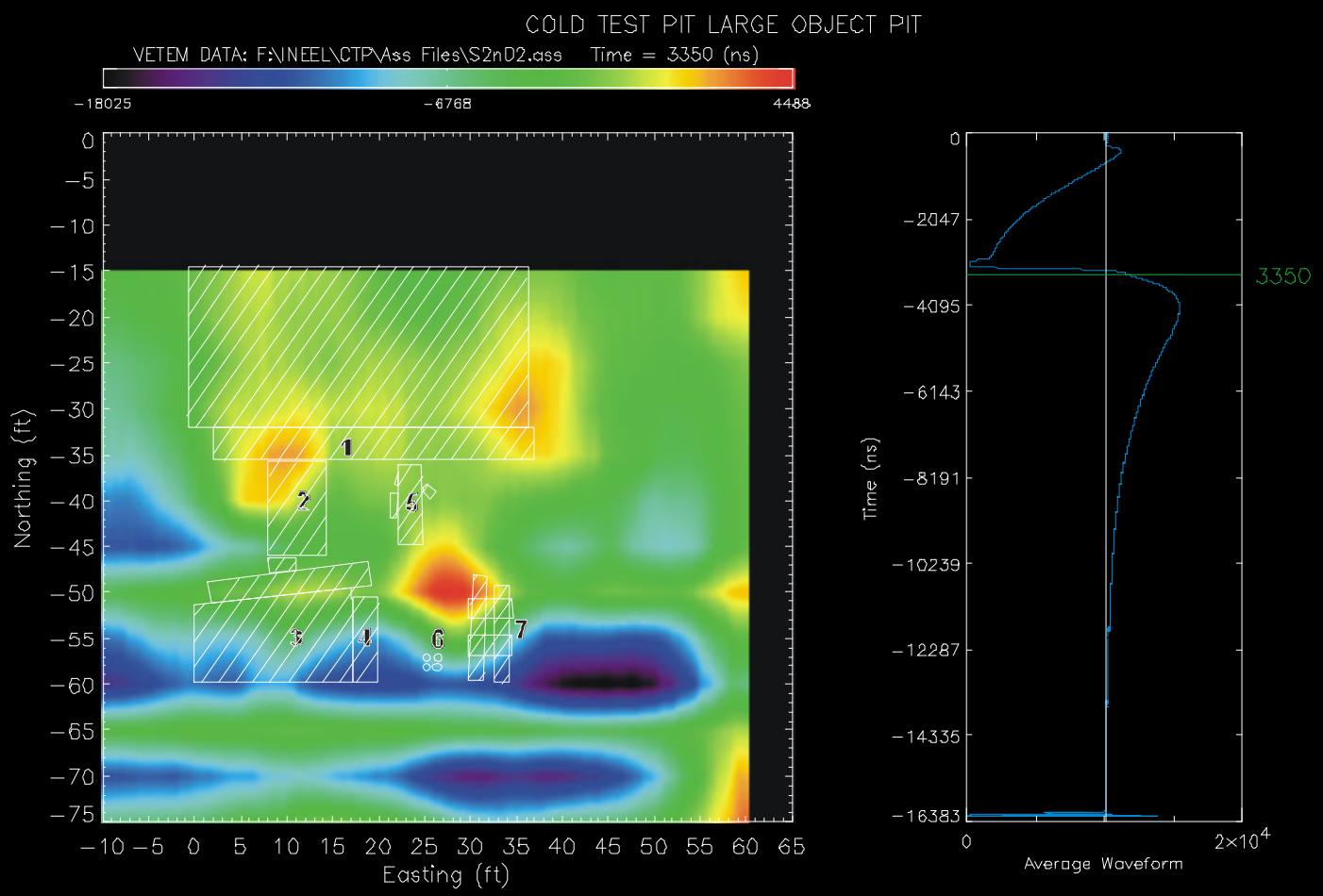
VETEM DATA: F:\INEEL\CTP\Ass Files\S2n02.ass Time = 2950 (ns)
-13661
-5261
3139
Northing (ft)
Easting (ft)
1
2
3
4
5
6
7
Time (ns)
2950
Average Waveform
2×10^4


COLD TEST PIT LARGE OBJECT PIT
VETEM DATA: F:\INEEL\CTP\Ass Files\S2n02.ass Time = 3000 (ns)
-10934
-3448
4038
Northing (ft)
Easting (ft)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
-65
-70
-75
-10 -5 0 5 10 15 20 25 30 35 40 45 50 55 60 65
1
2
3
4
5
6
7
Time (ns)
0
-2047
-4095
-6143
-8191
-10239
-12287
-14335
-16383
3000
0
2x10^4
Average Waveform


COLD TEST PIT LARGE OBJECT PIT
VETEM DATA: F:\INEEL\CTP\Ass Files\S2n02.ass Time = 3300 (ns)
-26697
-11761
3174
Northing (ft)
Easting (ft)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
-65
-70
-75
-10 -5 0 5 10 15 20 25 30 35 40 45 50 55 60 65
1
2
3
4
5
6
7
Time (ns)
0
-2047
-4095
-6143
-8191
-10239
-12287
-14335
-16383
3300
0
2x10^4
Average Waveform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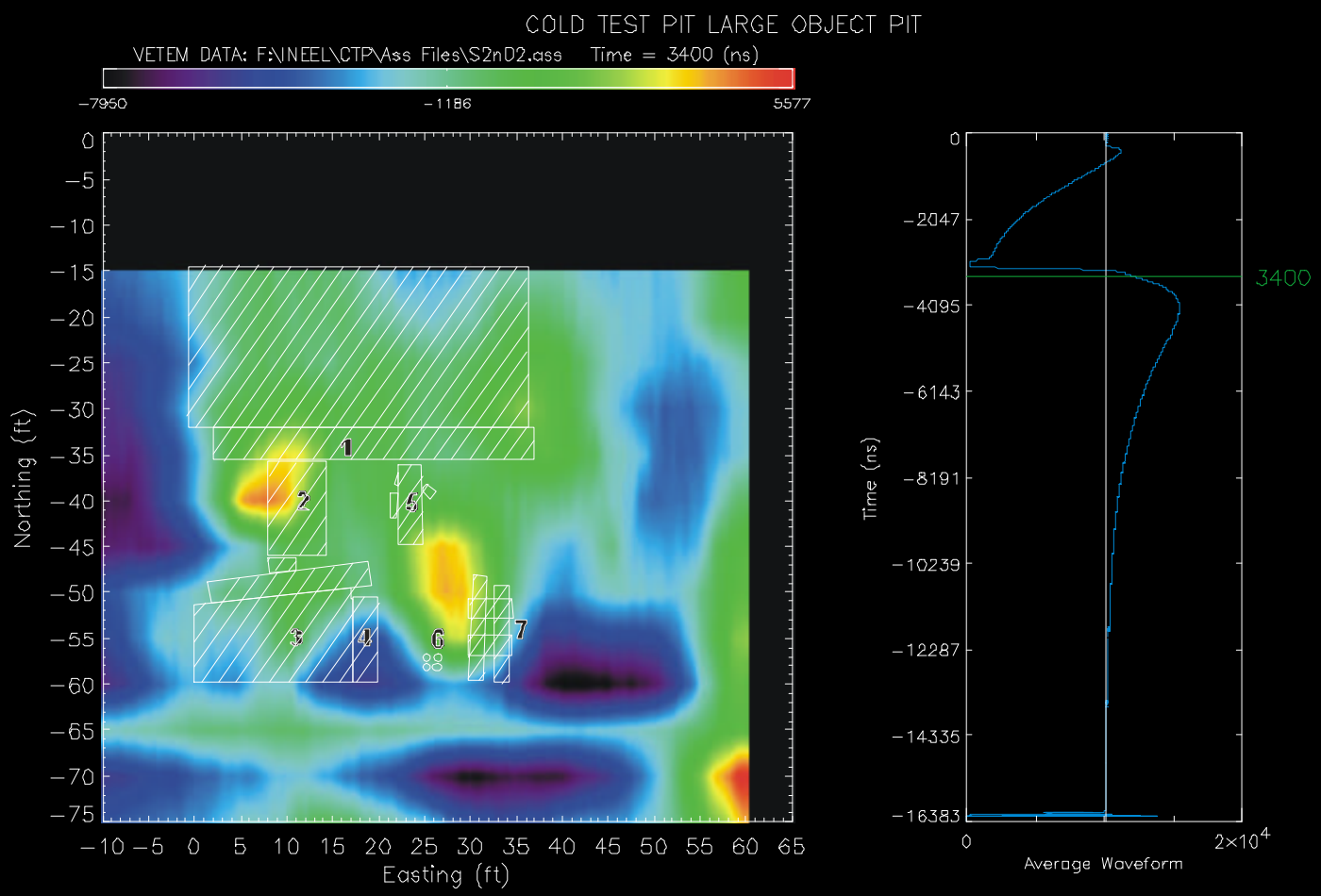
VETEM DATA: F:\INEEL\CTP\Ass Files\S2n02.ass Time = 3350 (ns)
-18025
-6768
4488
Northing (ft)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
-65
-70
-75
-10 -5 0 5 10 15 20 25 30 35 40 45 50 55 60 65
Easting (ft)
1
2
3
4
5
6
7
Time (ns)
0
-2047
-4095
-6143
-8191
-10239
-12287
-14335
-16383
3350
0
2×10^4
Average Waveform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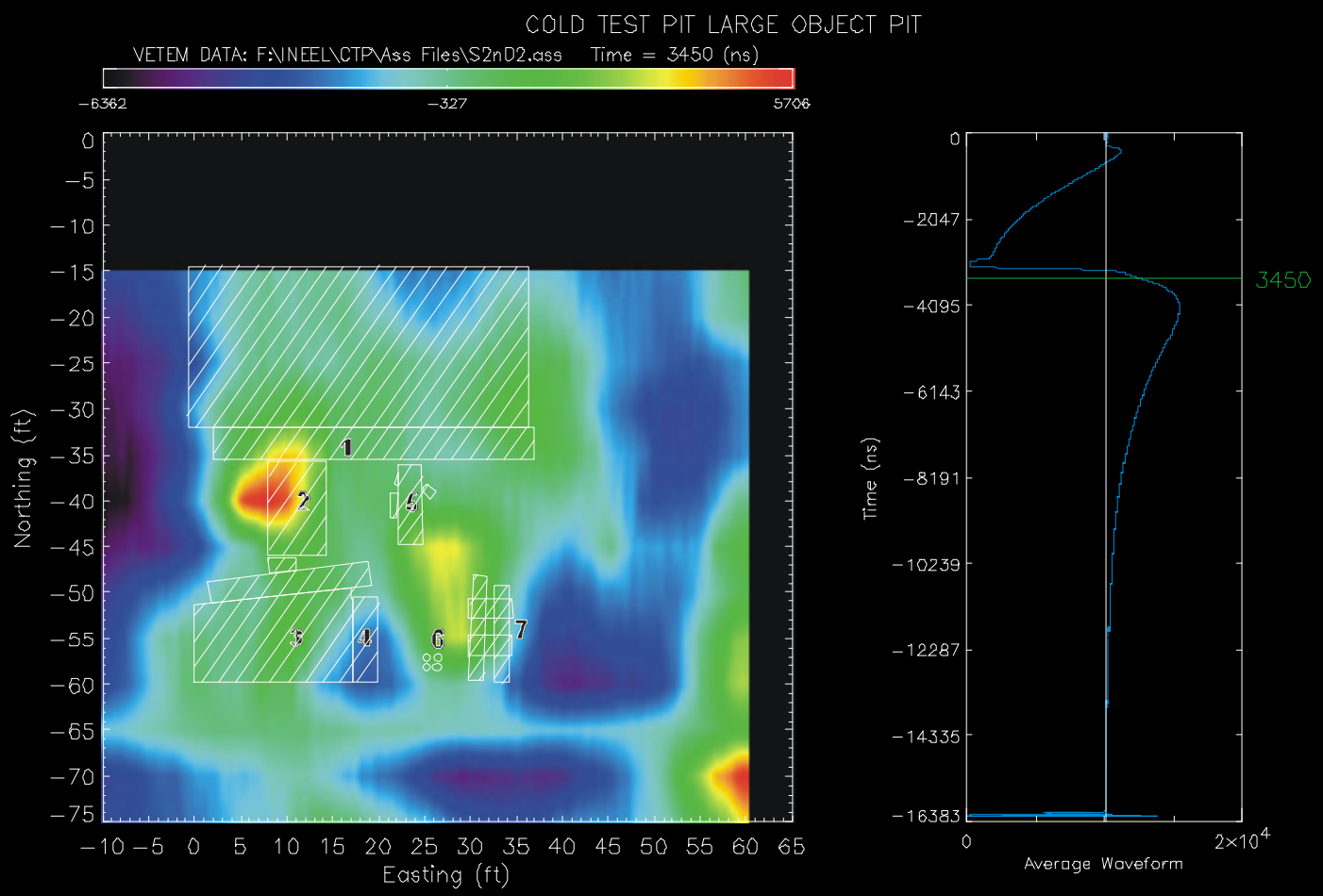
VETEM DATA: F:\INEEL\CTP\Ass Files\S2n02.ass Time = 3400 (ns)
-7960
-1186
5577
Northing (ft)
Easting (ft)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
-65
-70
-75
-10 -5 0 5 10 15 20 25 30 35 40 45 50 55 60 65
1
2
3
4
5
6
7
Time (ns)
0
-2047
-4095
-6143
-8191
-10239
-12287
-14335
-16383
3400
0
2x10^4
Average Waveform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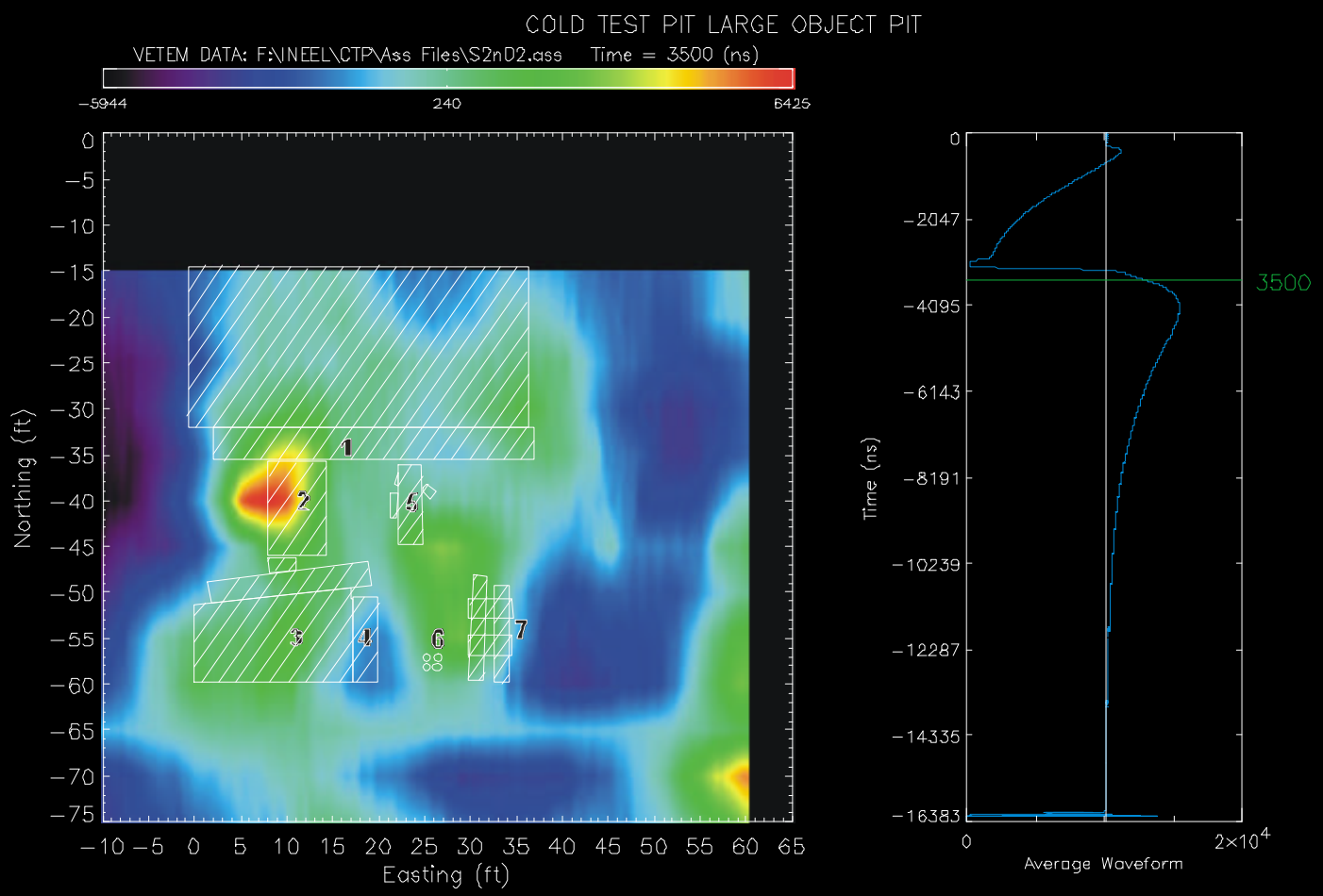
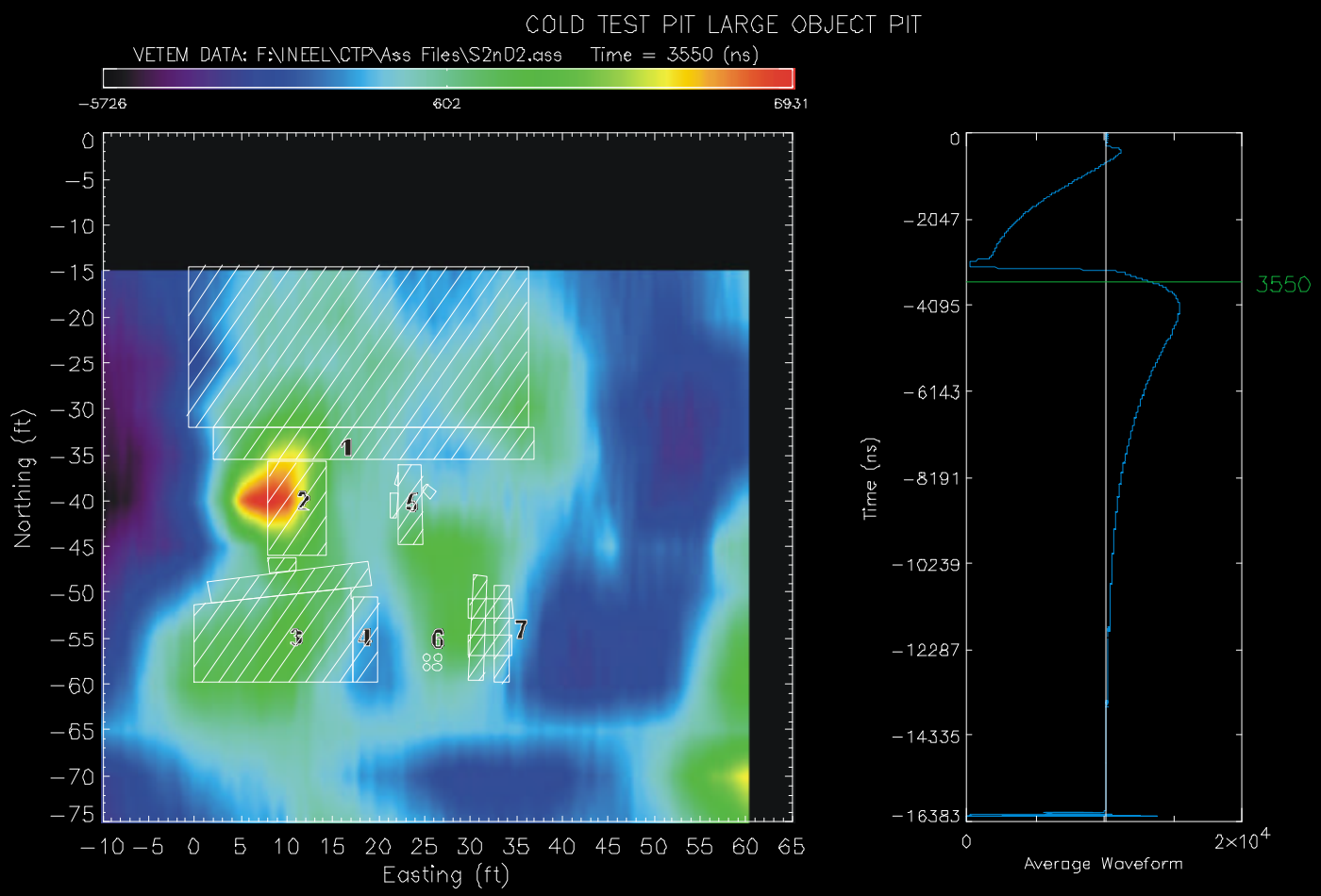
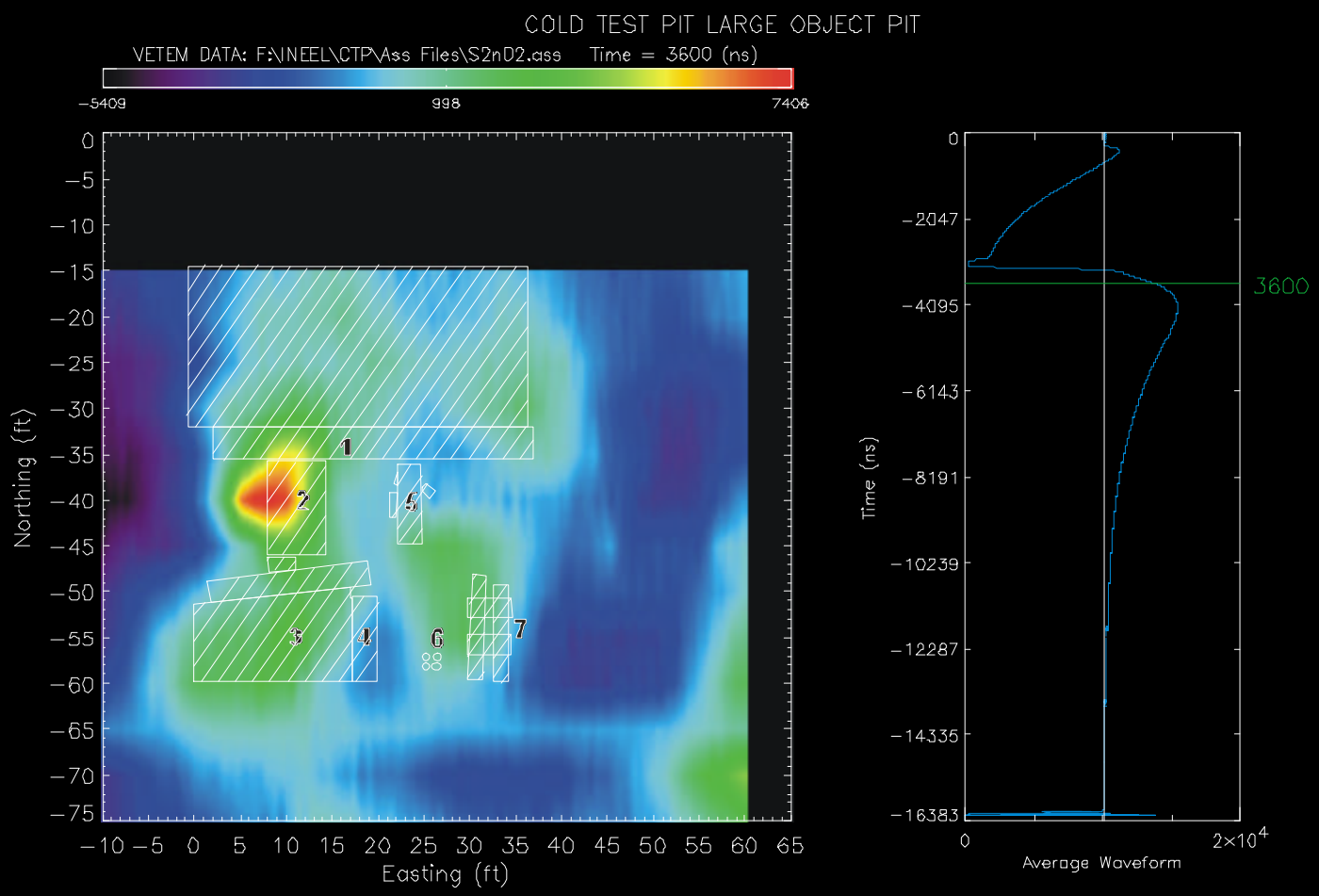
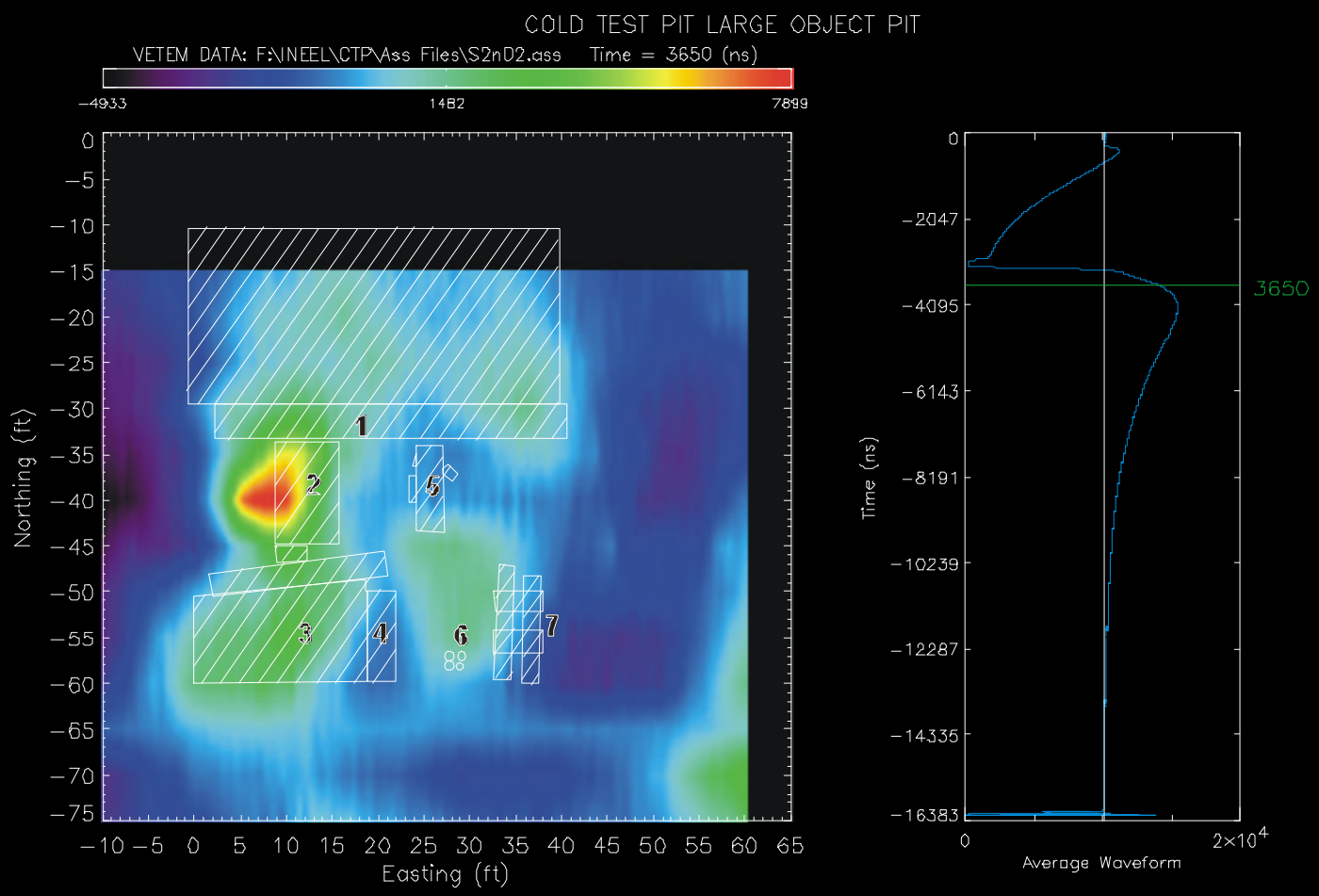
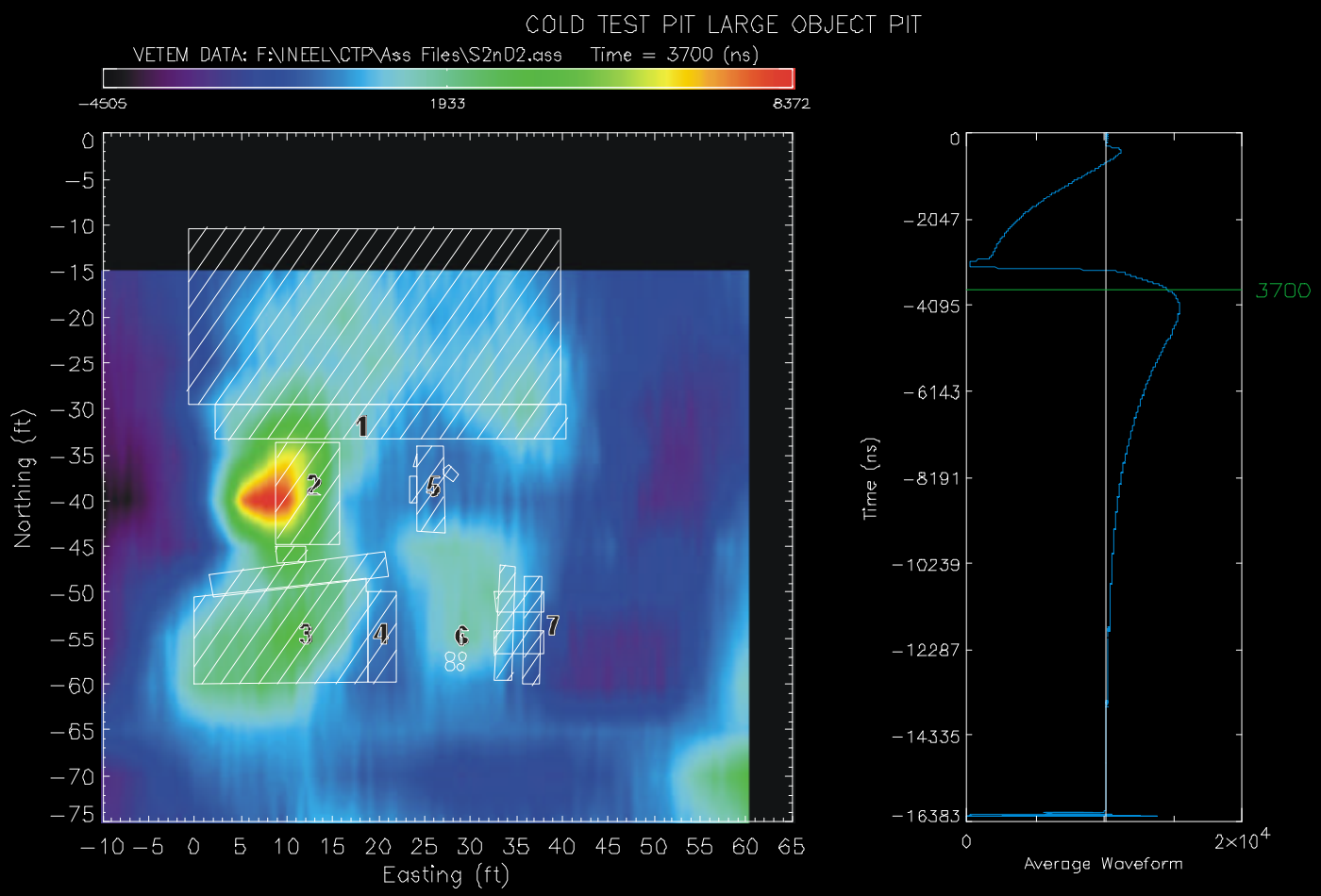
VETEM DATA: F:\INEEL\CTP\Ass Files\S2n02.ass Time = 3450 (ns)
-6362
-327
5706
Northing (ft)
Easting (ft)
1
2
3
4
5
6
7
Time (ns)
3450
Average Waveform
2×10^4

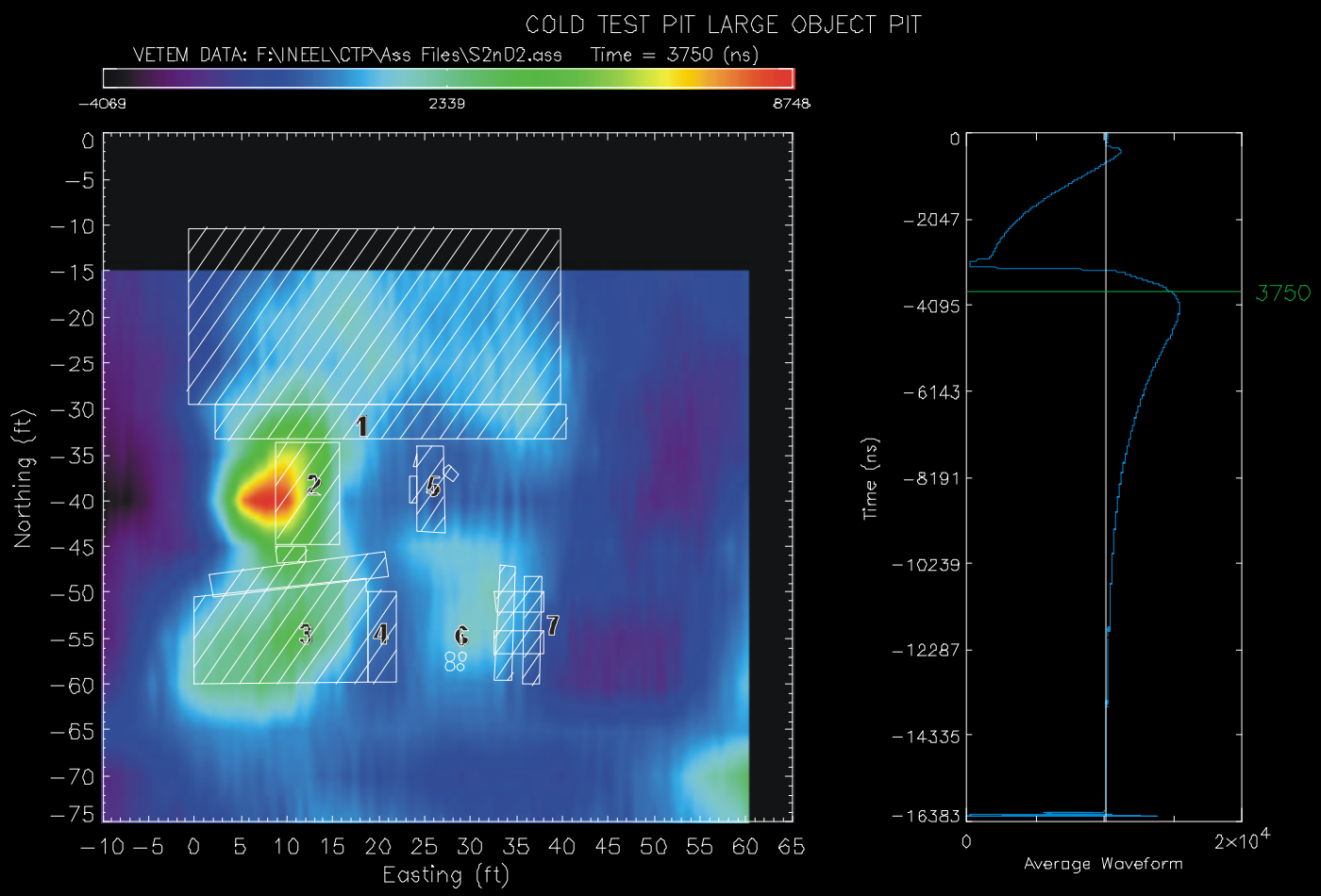

COLD TEST PIT LARGE OBJECT PIT
VETEM DATA: F:\INEEL\CTP\Ass Files\S2n02.ass Time = 3500 (ns)
-5944
240
6425
Northing (ft)
Easting (ft)
1
2
3
4
5
6
7
Time (ns)
3500
Average Waveform
2×10^4

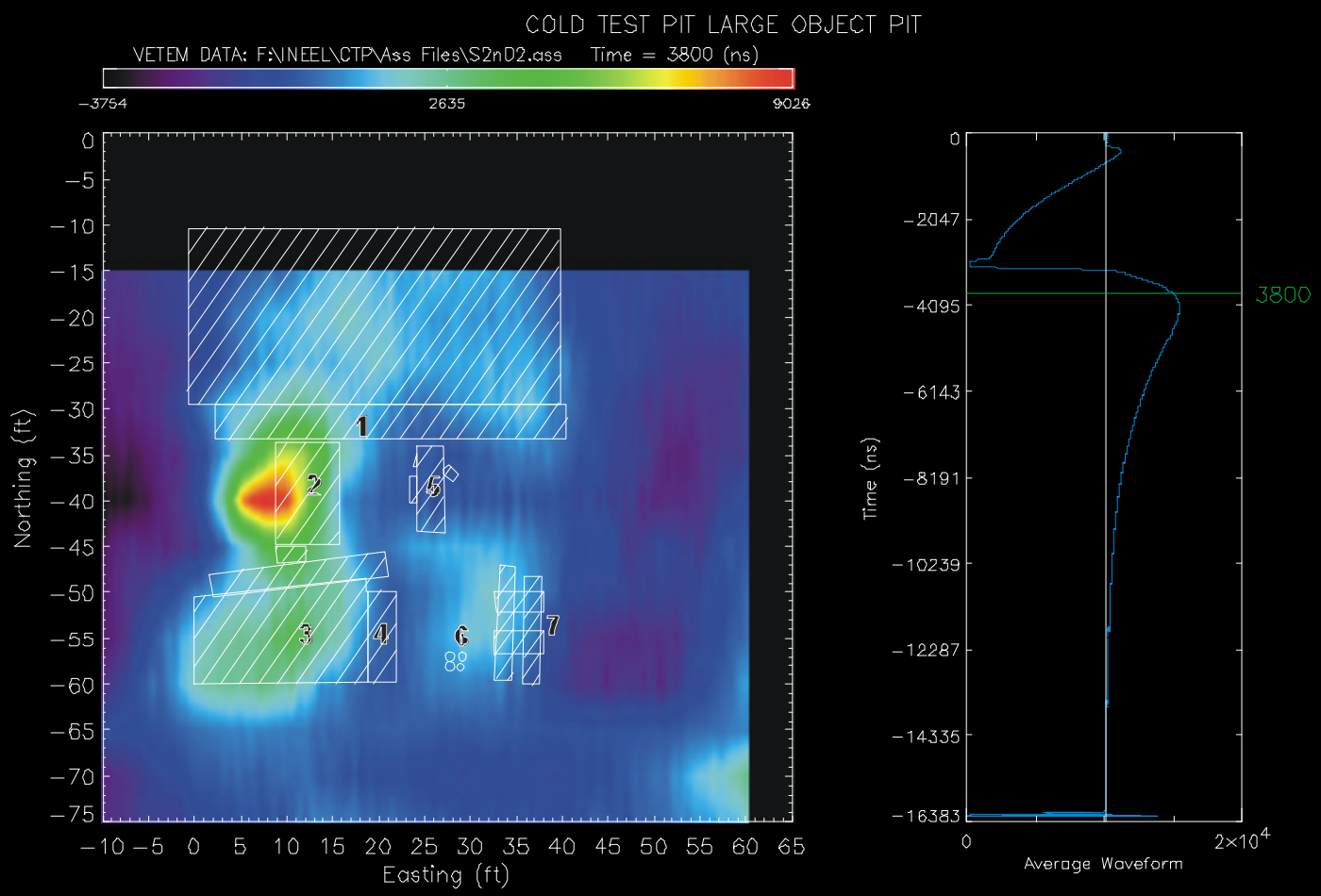

COLD TEST PIT LARGE OBJECT PIT
VETEM DATA: F:\INEEL\CTP\Ass Files\S2n02.ass Time = 3550 (ns)
-5726
602
6931
Northing (ft)
Easting (ft)
1
2
3
4
5
6
7
Time (ns)
3550
Average Waveform
2×10^4

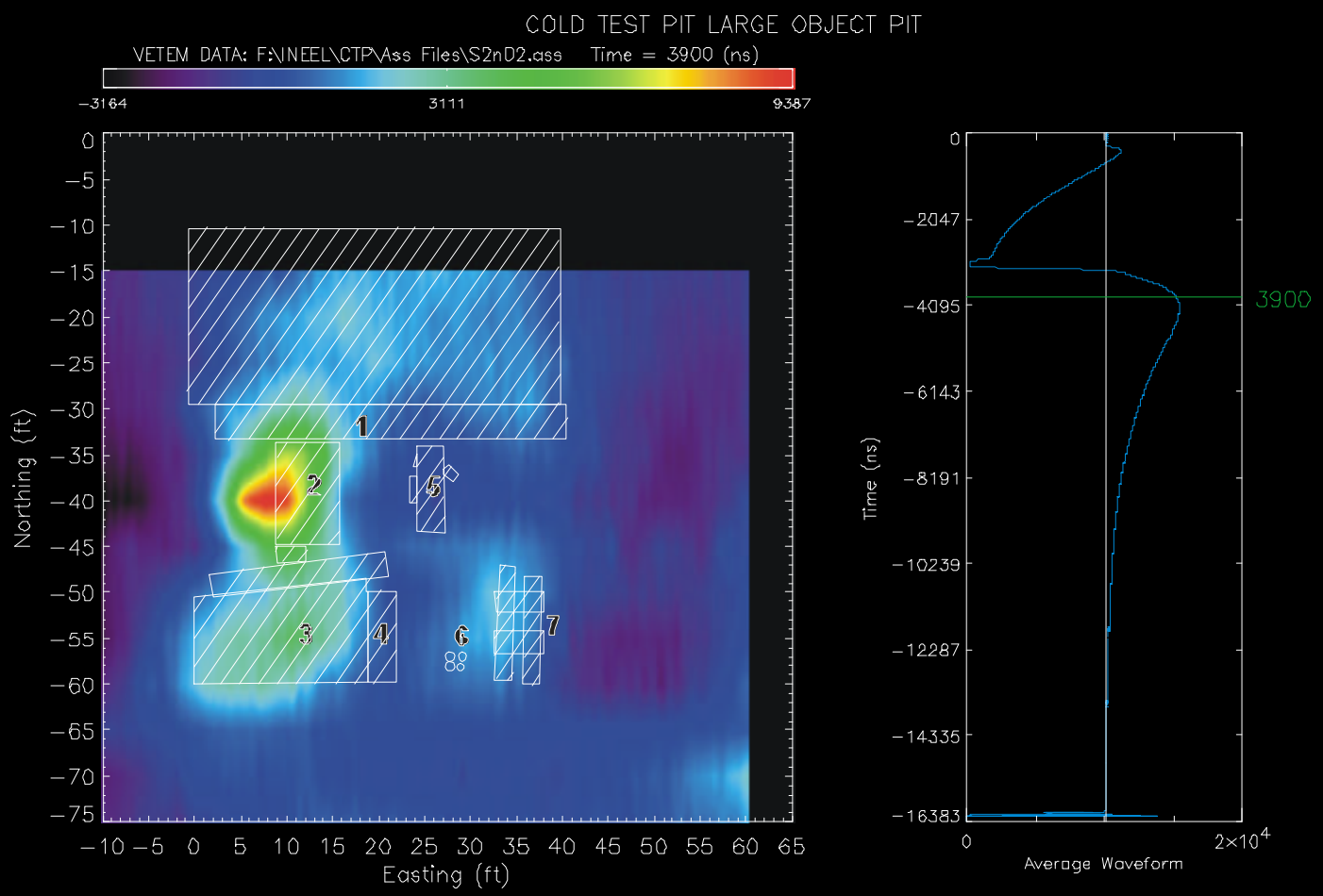

COLD TEST PIT LARGE OBJECT PIT
VETEM DATA: F:\INEEL\CTP\Ass Files\S2n02.ass Time = 3600 (ns)
-5409
998
7406
Northing (ft)
Easting (ft)
1
2
3
4
5
6
7
Time (ns)
3600
Average Waveform

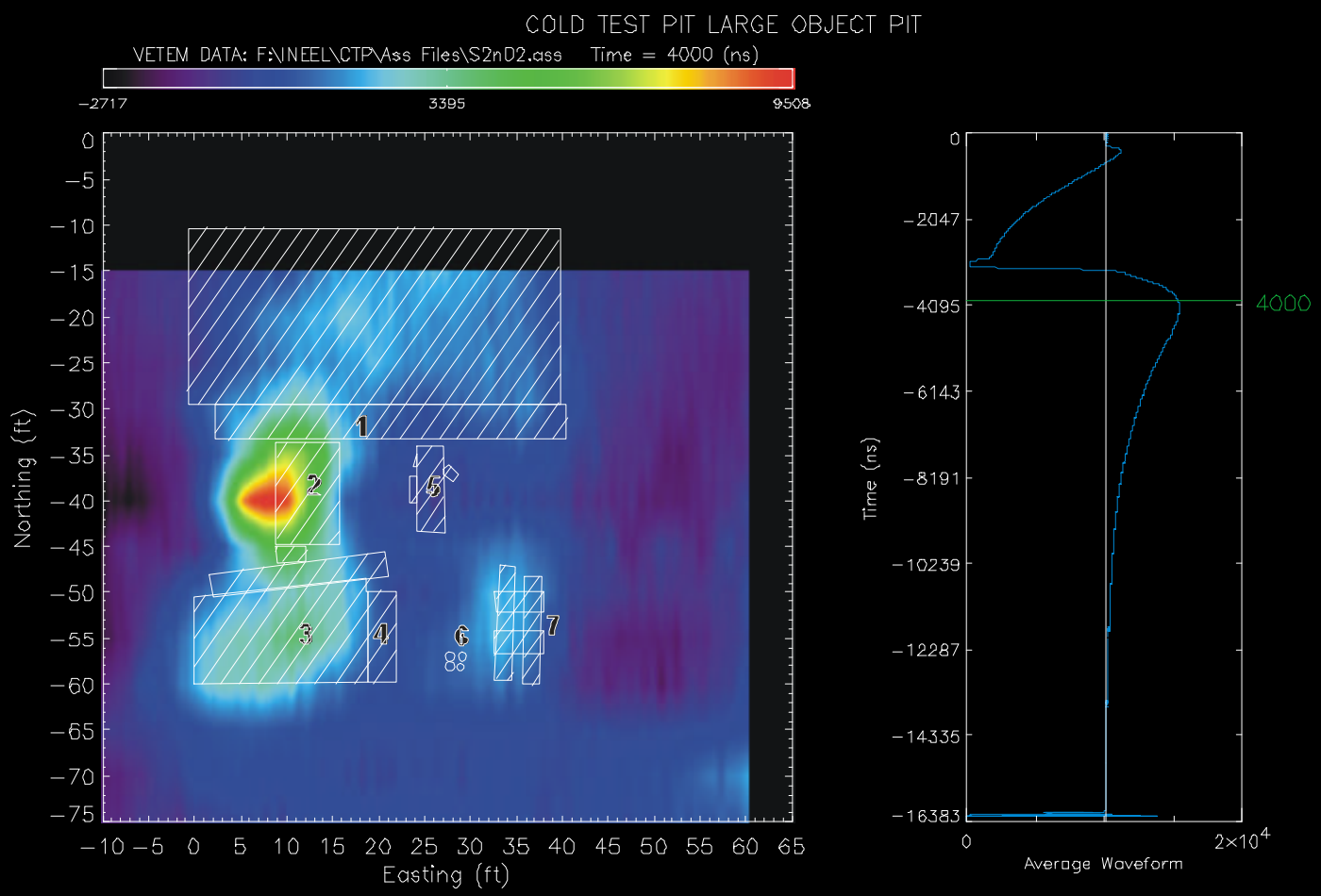

COLD TEST PIT LARGE OBJECT PIT
VETEM DATA: F:\INEEL\CTP\Ass Files\S2n02.ass Time = 3650 (ns)
-4933
1482
7899
Northing (ft)
Easting (ft)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
-65
-70
-75
-10 -5 0 5 10 15 20 25 30 35 40 45 50 55 60 65
1
2
3
4
5
6
7
Time (ns)
0
-2047
-4095
-6143
-8191
-10239
-12287
-14335
-16383
3650
0
2x10^4
Average Waveform

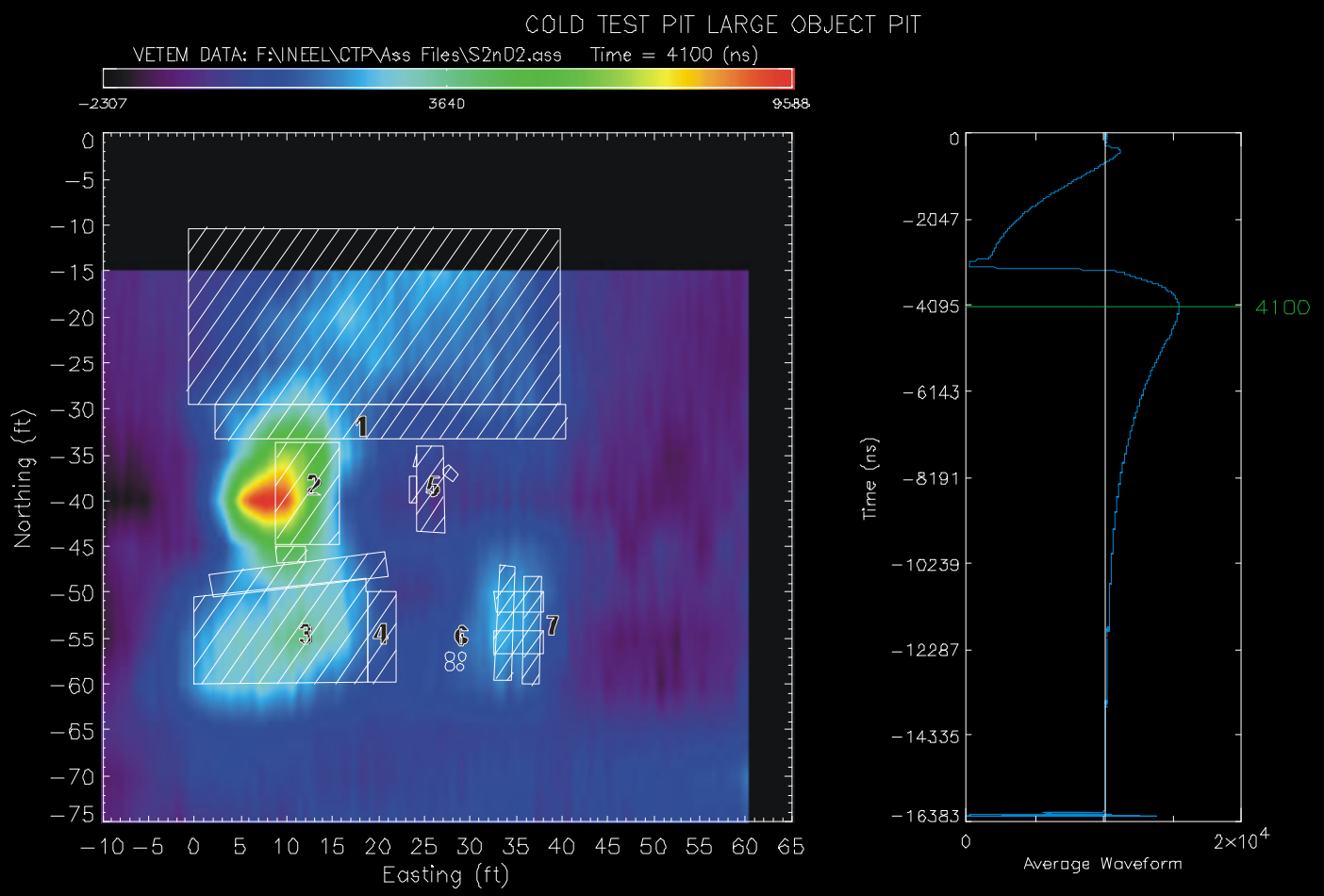

COLD TEST PIT LARGE OBJECT PIT
VETEM DATA: F:\INEEL\CTP\Ass Files\S2n02.ass Time = 3700 (ns)
-4505
1933
8372
Northing (ft)
Easting (ft)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
-65
-70
-75
-10 -5 0 5 10 15 20 25 30 35 40 45 50 55 60 65
1
2
3
4
5
6
7
Time (ns)
0
-2047
-4095
-6143
-8191
-10239
-12287
-14335
-16383
3700
0
2x10^4
Average Waveform

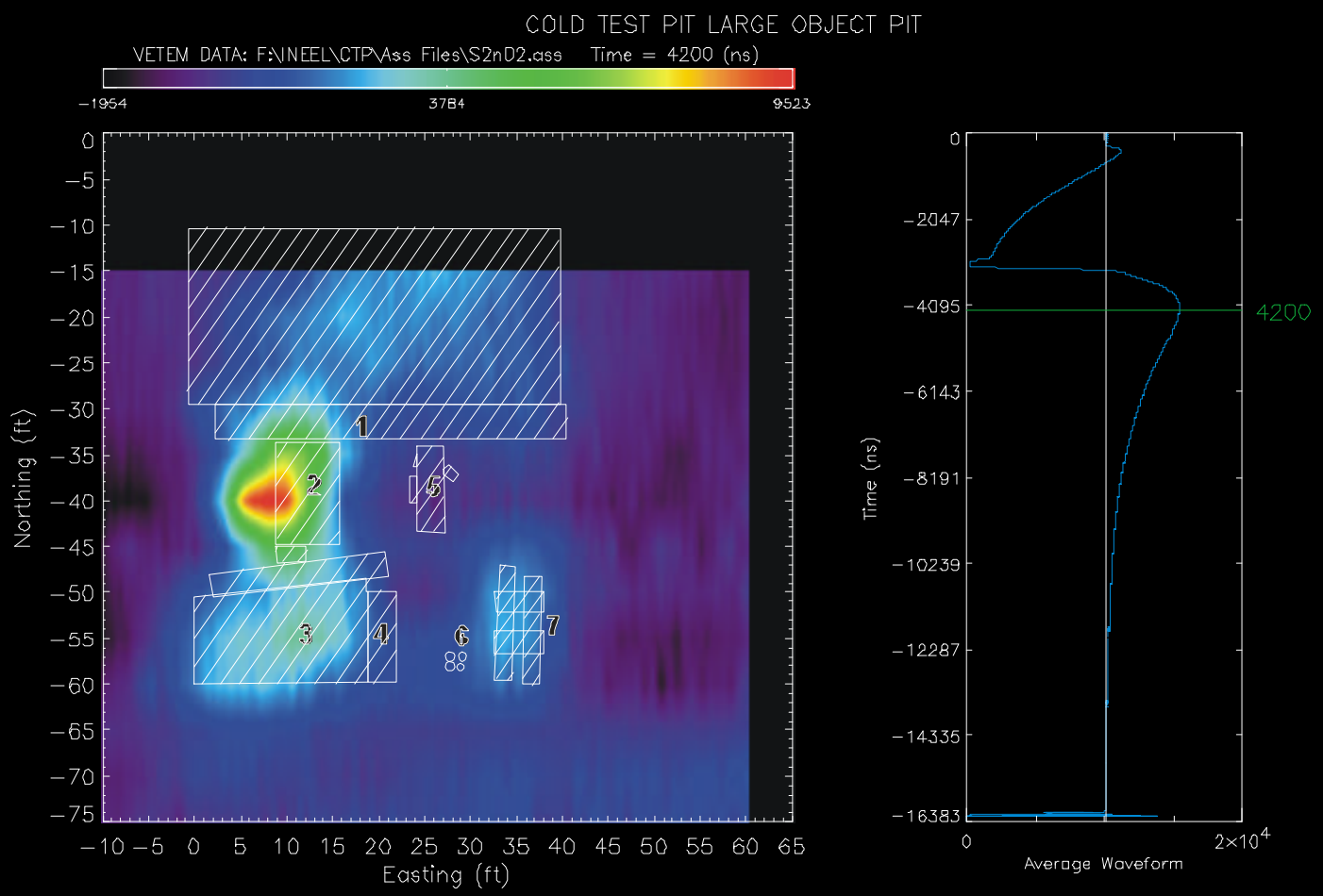

COLD TEST PIT LARGE OBJECT PIT
VETEM DATA: F:\INEEL\CTP\Ass Files\S2n02.ass Time = 3750 (ns)
-4069
2339
8748
Northing (ft)
Easting (ft)
1
2
3
4
5
6
7
Time (ns)
Average Waveform
3750

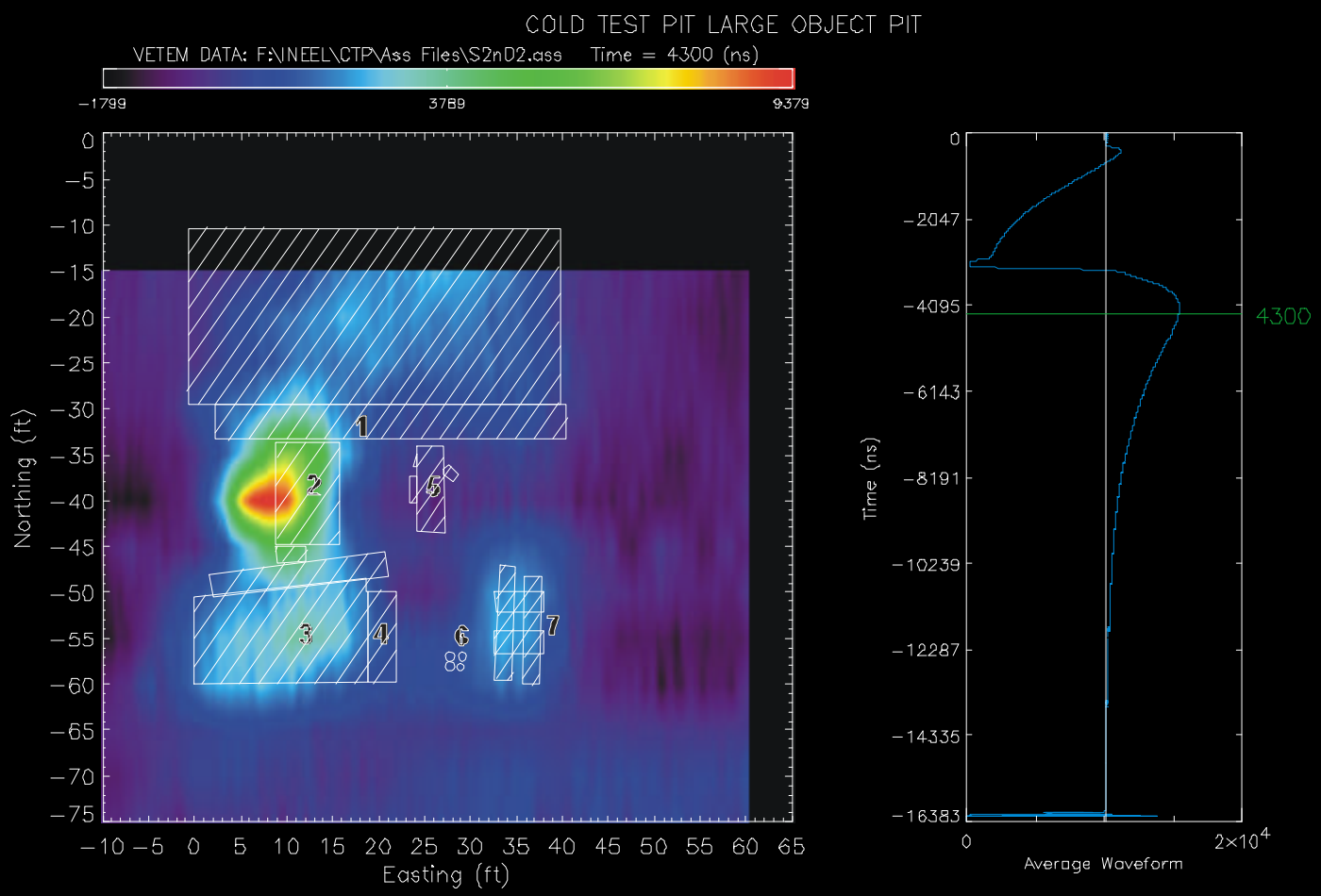

COLD TEST PIT LARGE OBJECT PIT
VETEM DATA: F:\INEEL\CTP\Ass Files\S2n02.ass Time = 3800 (ns)
-3754
2635
9026
Northing (ft)
Easting (ft)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
-65
-70
-75
-10 -5 0 5 10 15 20 25 30 35 40 45 50 55 60 65
1
2
3
4
5
6
7
Time (ns)
0
-2047
-4095
-6143
-8191
-10239
-12287
-14335
-16383
3800
0
2x10^4
Average Waveform

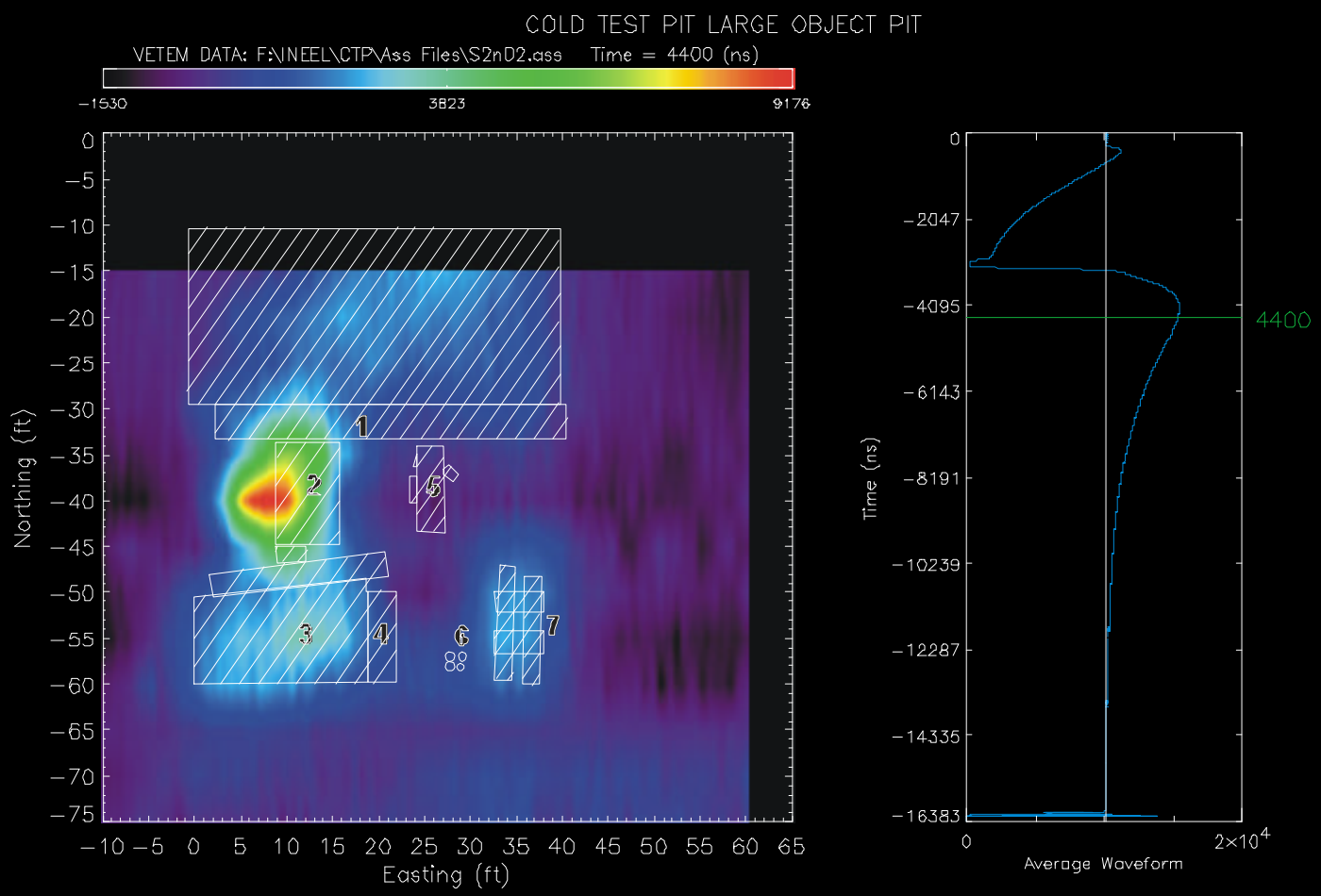

COLD TEST PIT LARGE OBJECT PIT
VETEM DATA: F:\INEEL\CTP\Ass Files\S2n02.ass Time = 3900 (ns)
−3164
3111
9387
Northing (ft)
0
−5
−10
−15
−20
−25
−30
−35
−40
−45
−50
−55
−60
−65
−70
−75
−10 −5 0 5 10 15 20 25 30 35 40 45 50 55 60 65
Easting (ft)
1
2
3
4
5
6
7
Time (ns)
0
−2047
−4095
−6143
−8191
−10239
−12287
−14335
−16383
3900
0
2×10^4
Average Waveform

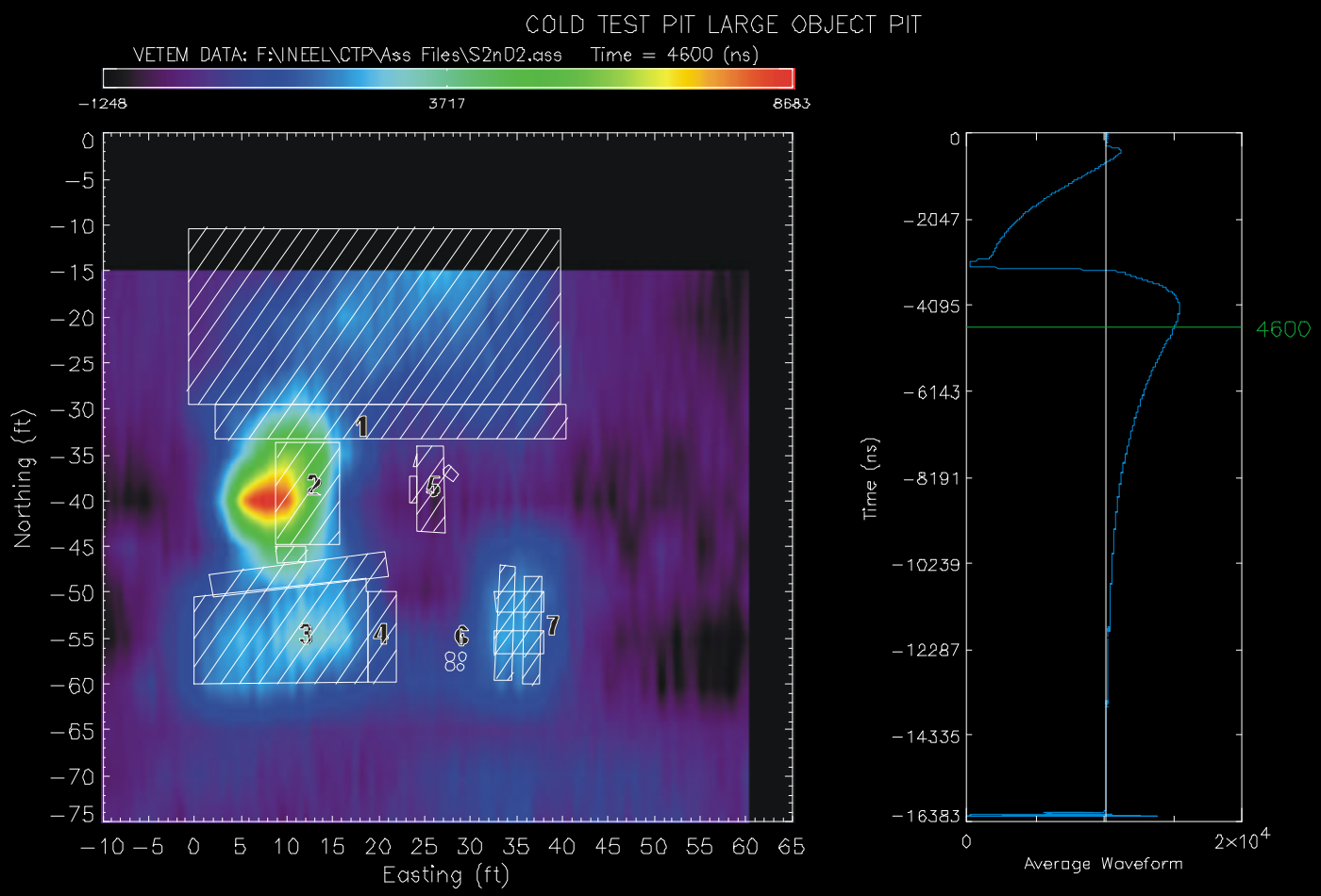

COLD TEST PIT LARGE OBJECT PIT
VETEM DATA: F:\INEEL\CTP\Ass Files\S2n02.ass Time = 4000 (ns)
-2717
3395
9508
Northing (ft)
Easting (ft)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
-65
-70
-75
-10 -5 0 5 10 15 20 25 30 35 40 45 50 55 60 65
1
2
3
4
5
6
7
Time (ns)
0
-2047
-4095
-6143
-8191
-10239
-12287
-14335
-16383
4000
0
2x10^4
Average Waveform

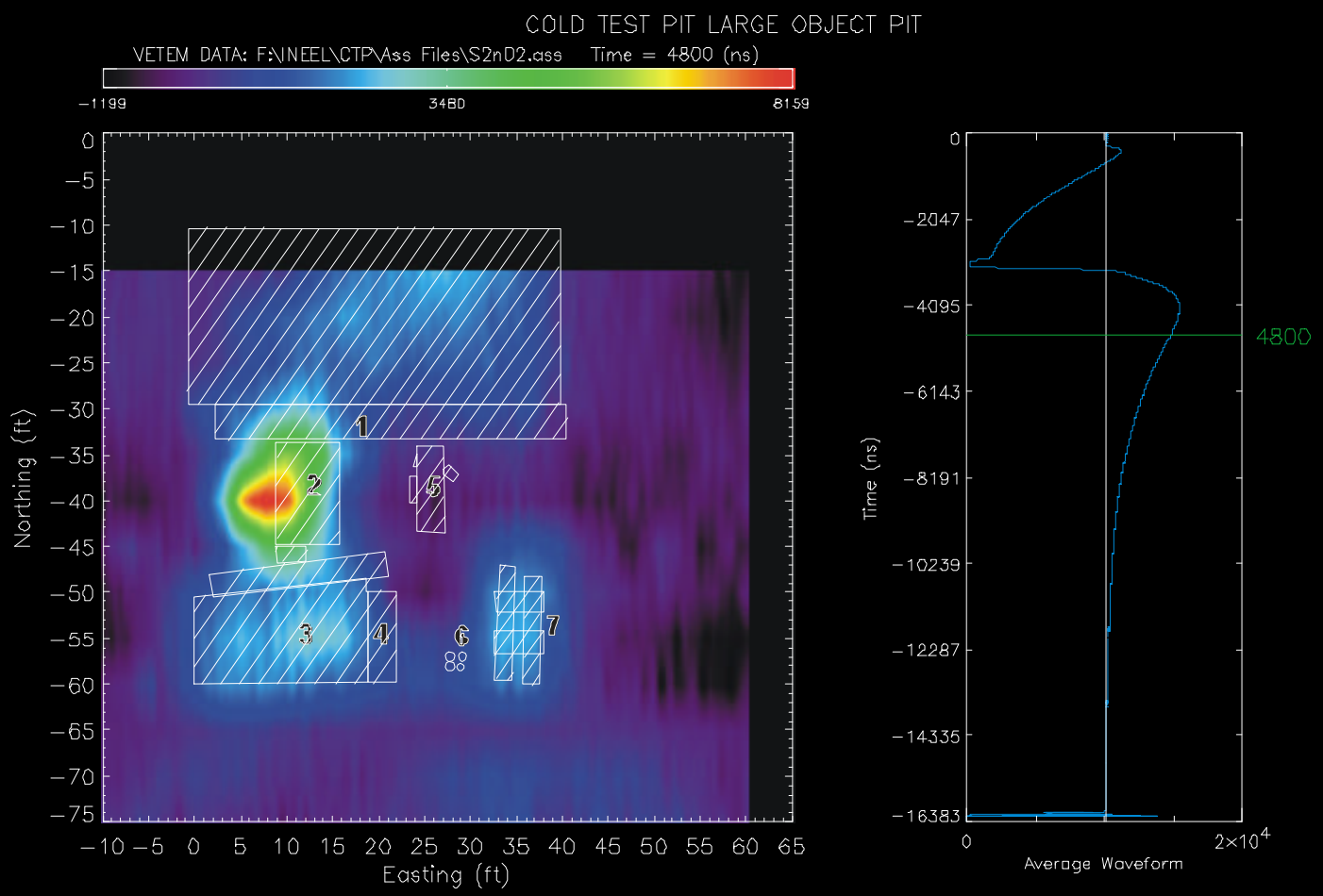

COLD TEST PIT LARGE OBJECT PIT
VETEM DATA: F:\INEEL\CTP\Ass Files\S2n02.ass Time = 4100 (ns)
-2307
3640
9588
Northing (ft)
Easting (ft)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
-65
-70
-75
-10 -5 0 5 10 15 20 25 30 35 40 45 50 55 60 65
1
2
3
4
5
6
7
Time (ns)
0
-2047
-4095
-6143
-8191
-10239
-12287
-14335
-16383
4100
0
2x10^4
Average Waveform

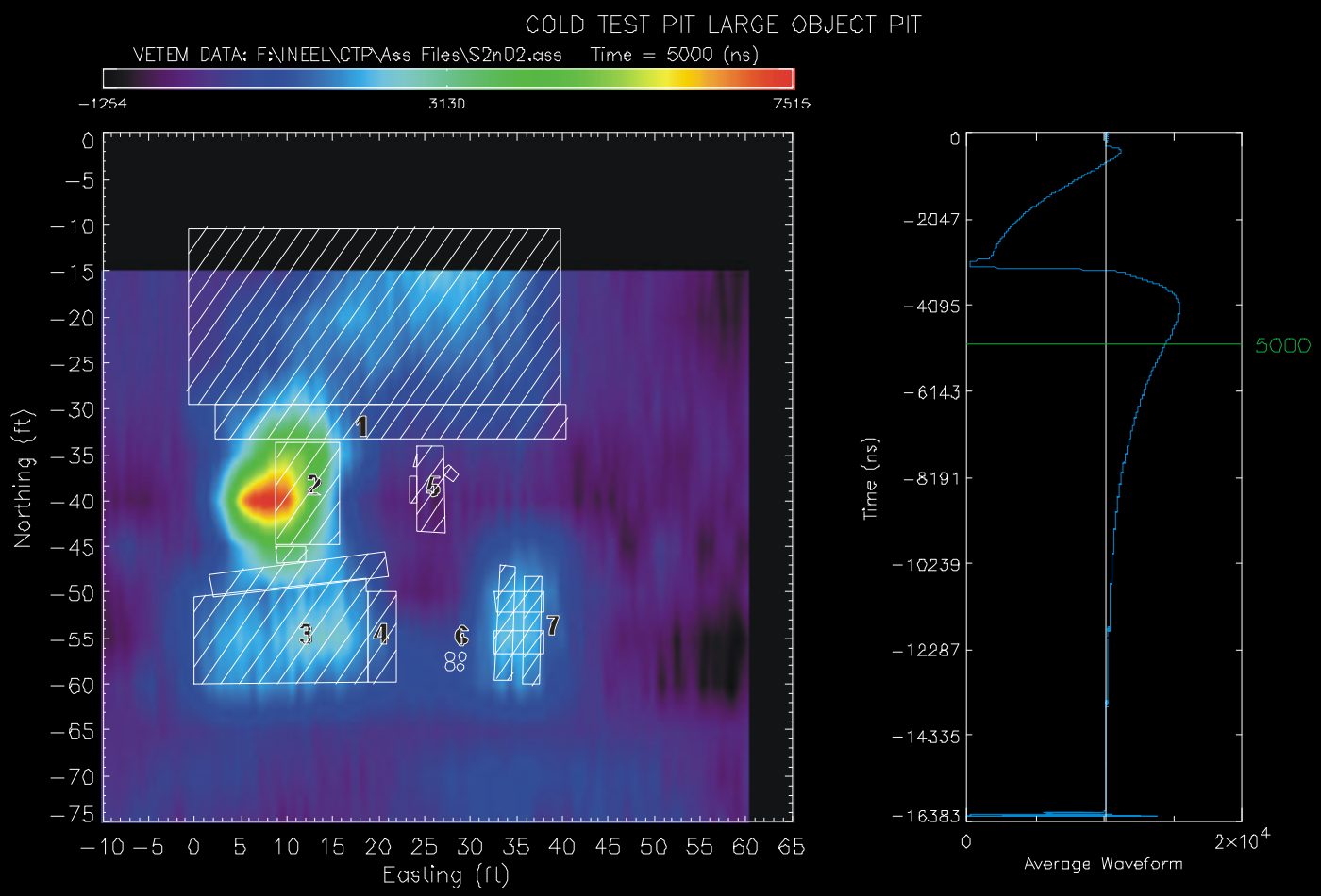

COLD TEST PIT LARGE OBJECT PIT
VETEM DATA: F:\INEEL\CTP\Ass Files\S2n02.ass Time = 4200 (ns)
-1954
3784
9523
Northing (ft)
Easting (ft)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
-65
-70
-75
-10 -5 0 5 10 15 20 25 30 35 40 45 50 55 60 65
1
2
3
4
5
6
7
Time (ns)
0
-2047
-4095
-6143
-8191
-10239
-12287
-14335
-16383
4200
0
2x10^4
Average Waveform

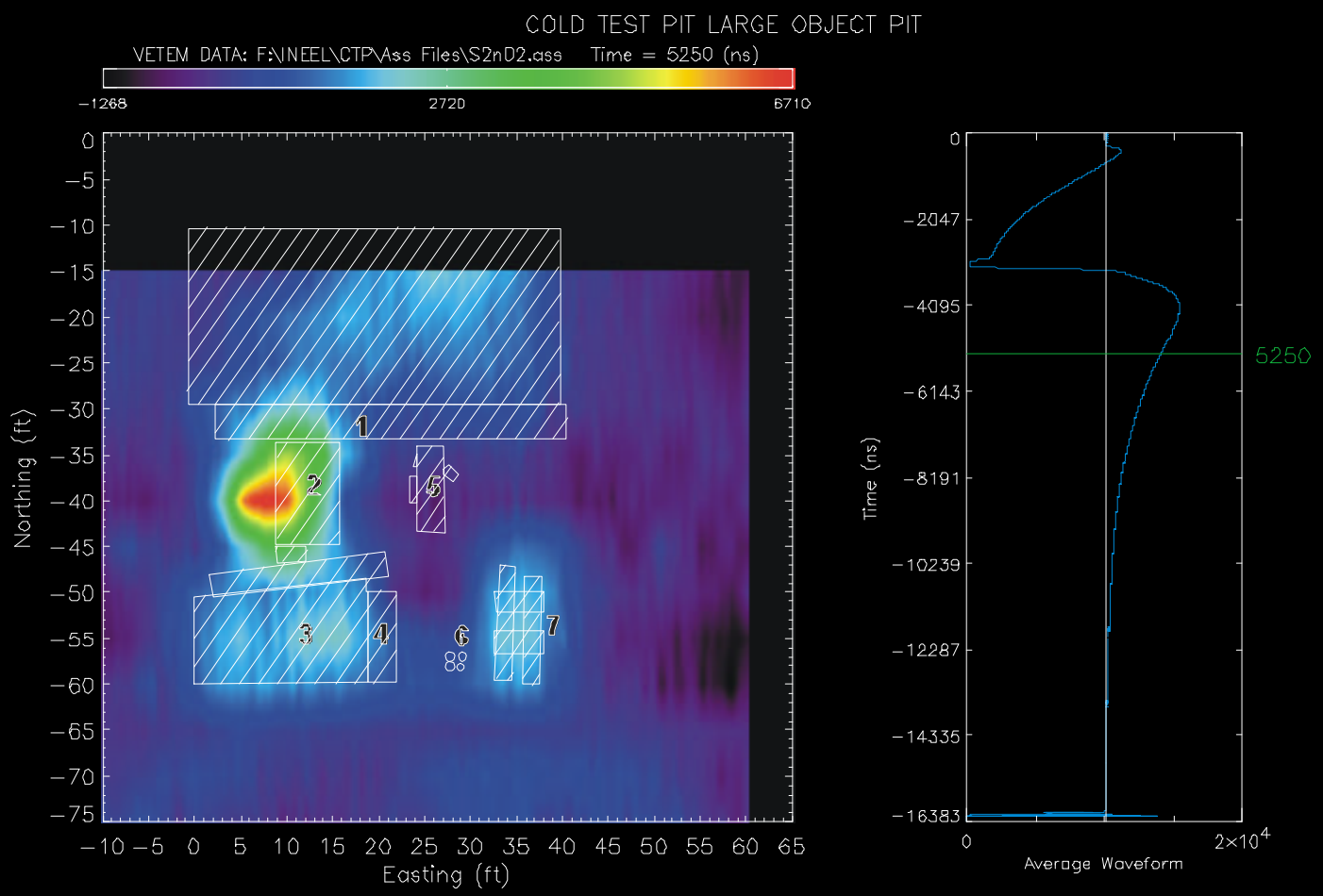

COLD TEST PIT LARGE OBJECT PIT
VETEM DATA: F:\INEEL\CTP\Ass Files\S2n02.ass Time = 4300 (ns)
-1799
3789
9379
Northing (ft)
Easting (ft)
1
2
3
4
5
6
7
Time (ns)
4300
Average Waveform

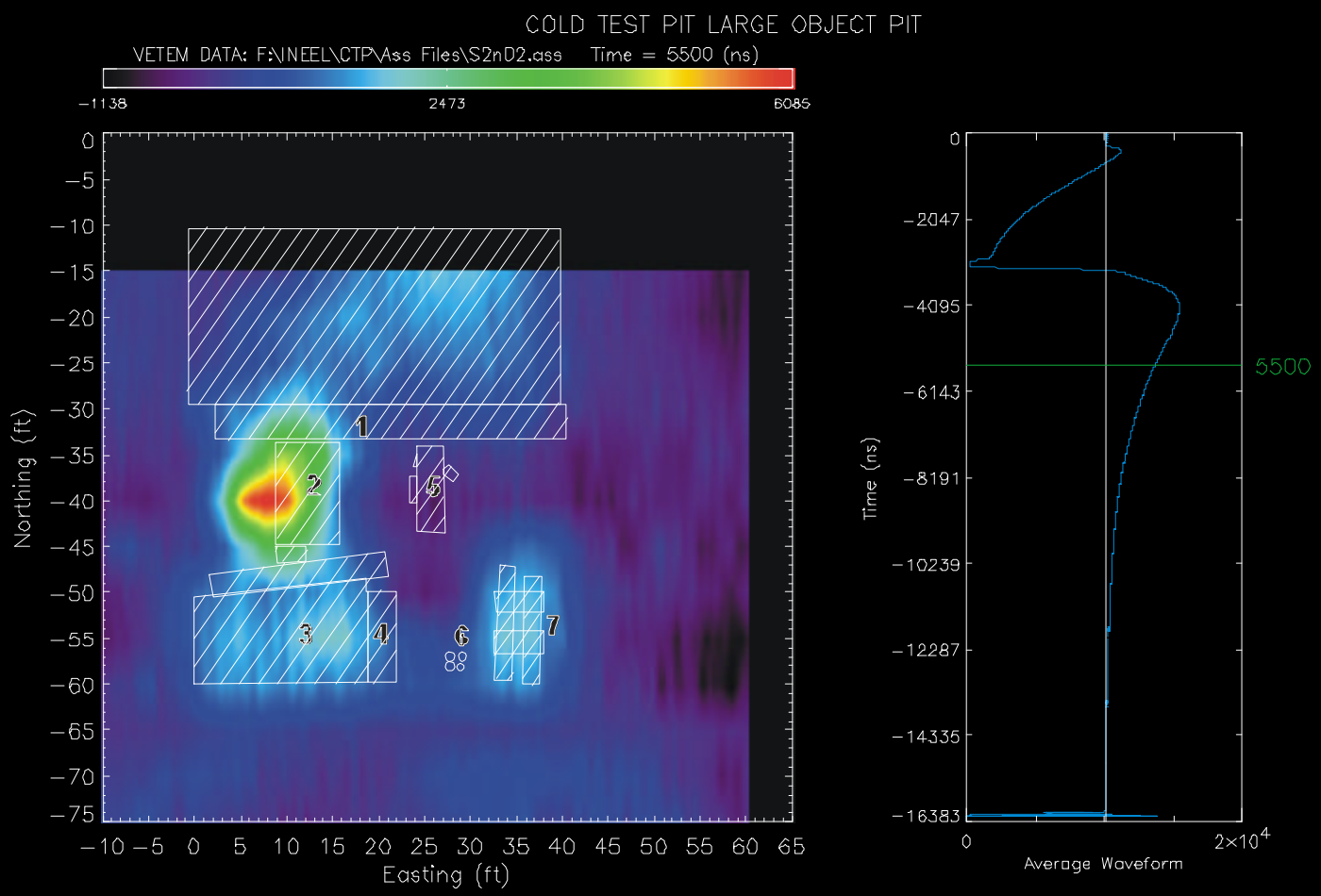

COLD TEST PIT LARGE OBJECT PIT
VETEM DATA: F:\INEEL\CTP\Ass Files\S2n02.ass Time = 4400 (ns)
−1530
3823
9176
Northing (ft)
Easting (ft)
0
−5
−10
−15
−20
−25
−30
−35
−40
−45
−50
−55
−60
−65
−70
−75
−10 −5 0 5 10 15 20 25 30 35 40 45 50 55 60 65
1
2
3
4
5
6
7
Time (ns)
0
−2047
−4095
−6143
−8191
−10239
−12287
−14335
−16383
4400
0
2×10^4
Average Waveform

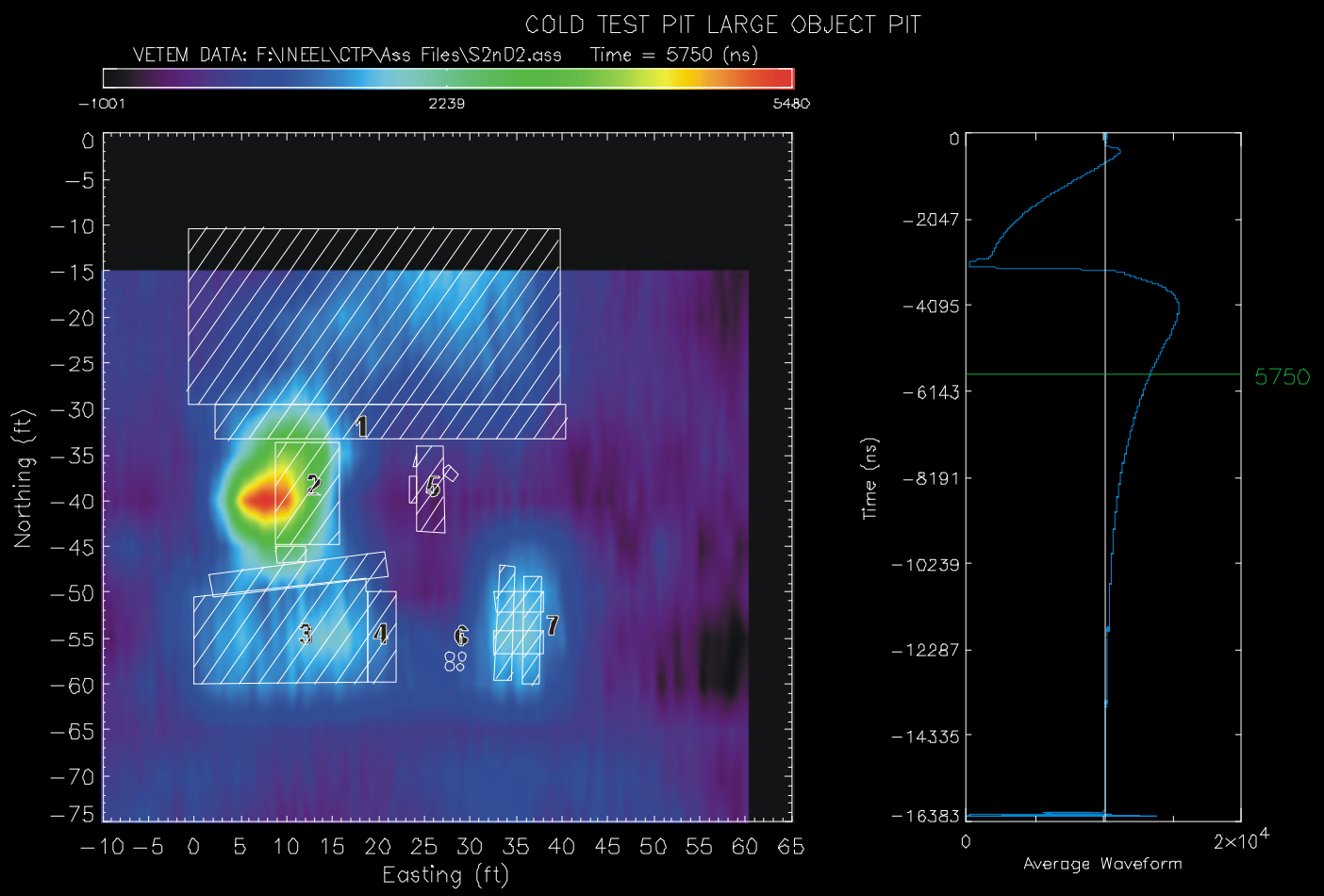

COLD TEST PIT LARGE OBJECT PIT
VETEM DATA: F:\INEEL\CTP\Ass Files\S2n02.ass Time = 4600 (ns)
-1248
3717
8683
Northing (ft)
Easting (ft)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
-65
-70
-75
-10 -5 0 5 10 15 20 25 30 35 40 45 50 55 60 65
1
2
3
4
5
6
7
Time (ns)
0
-2047
-4095
-6143
-8191
-10239
-12287
-14335
-16383
4600
0
2x10^4
Average Waveform

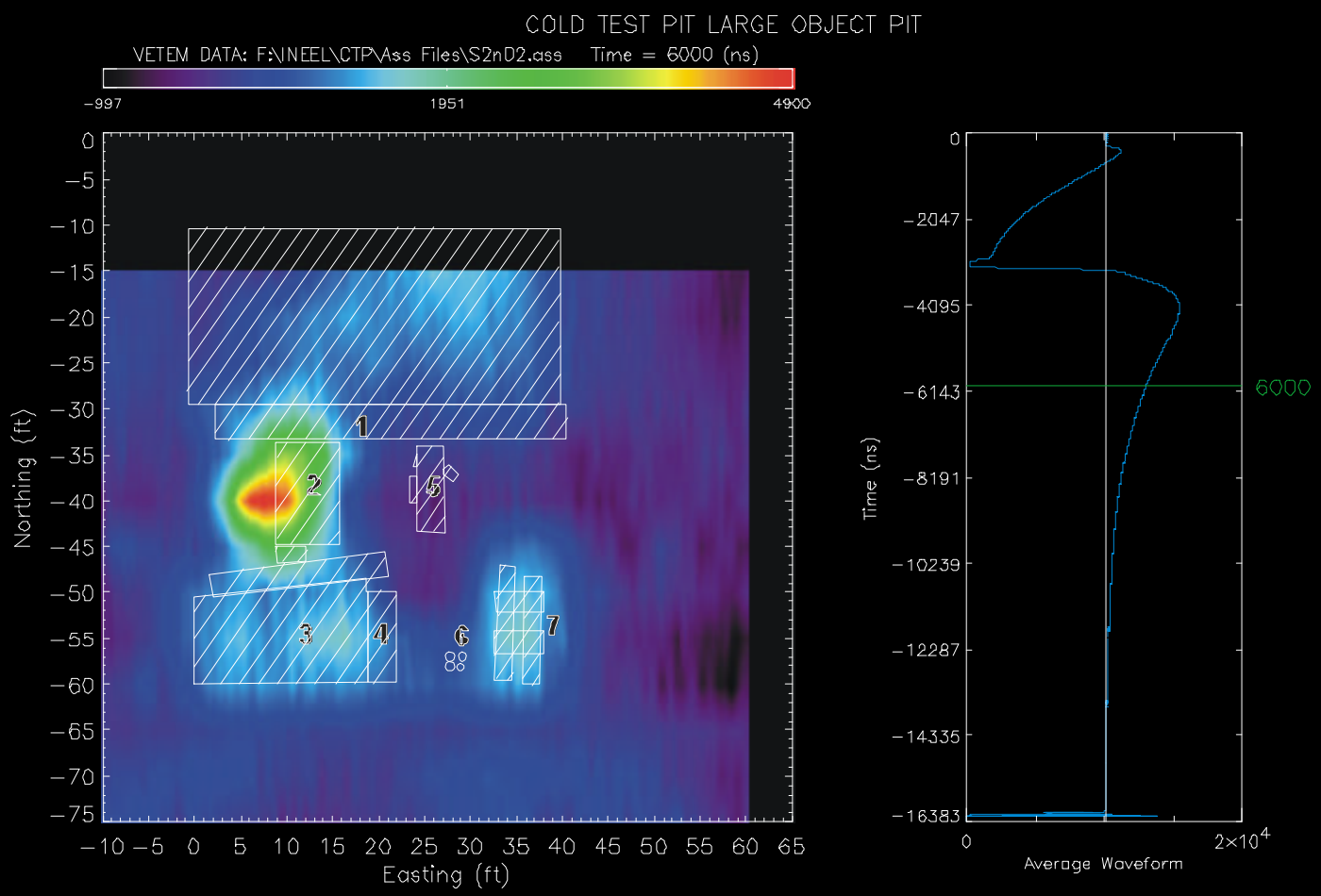

COLD TEST PIT LARGE OBJECT PIT
VETEM DATA: F:\INEEL\CTP\Ass Files\S2n02.ass Time = 4800 (ns)
-1199
3480
8159
Northing (ft)
Easting (ft)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
-65
-70
-75
-10 -5 0 5 10 15 20 25 30 35 40 45 50 55 60 65
1
2
3
4
5
6
7
Time (ns)
0
-2047
-4095
-6143
-8191
-10239
-12287
-14335
-16383
4800
0
2x10^4
Average Waveform

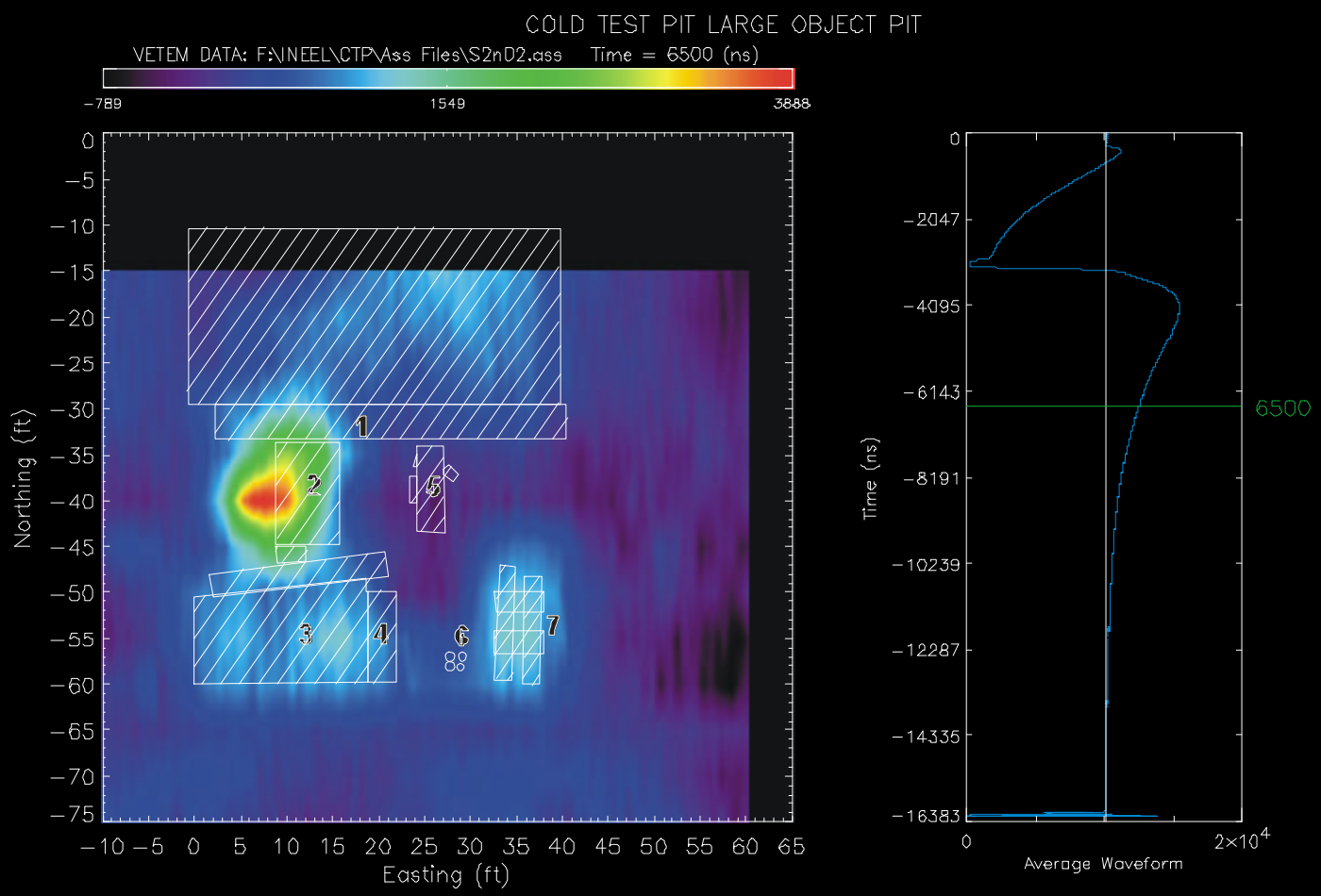

COLD TEST PIT LARGE OBJECT PIT
VETEM DATA: F:\INEEL\CTP\Ass Files\S2n02.ass Time = 5000 (ns)
−1254
3130
7515
Northing (ft)
Easting (ft)
0
−5
−10
−15
−20
−25
−30
−35
−40
−45
−50
−55
−60
−65
−70
−75
−10 −5 0 5 10 15 20 25 30 35 40 45 50 55 60 65
1
2
3
4
5
6
7
Time (ns)
0
−2047
−4095
−6143
−8191
−10239
−12287
−14335
−16383
5000
0
2×10^4
Average Waveform

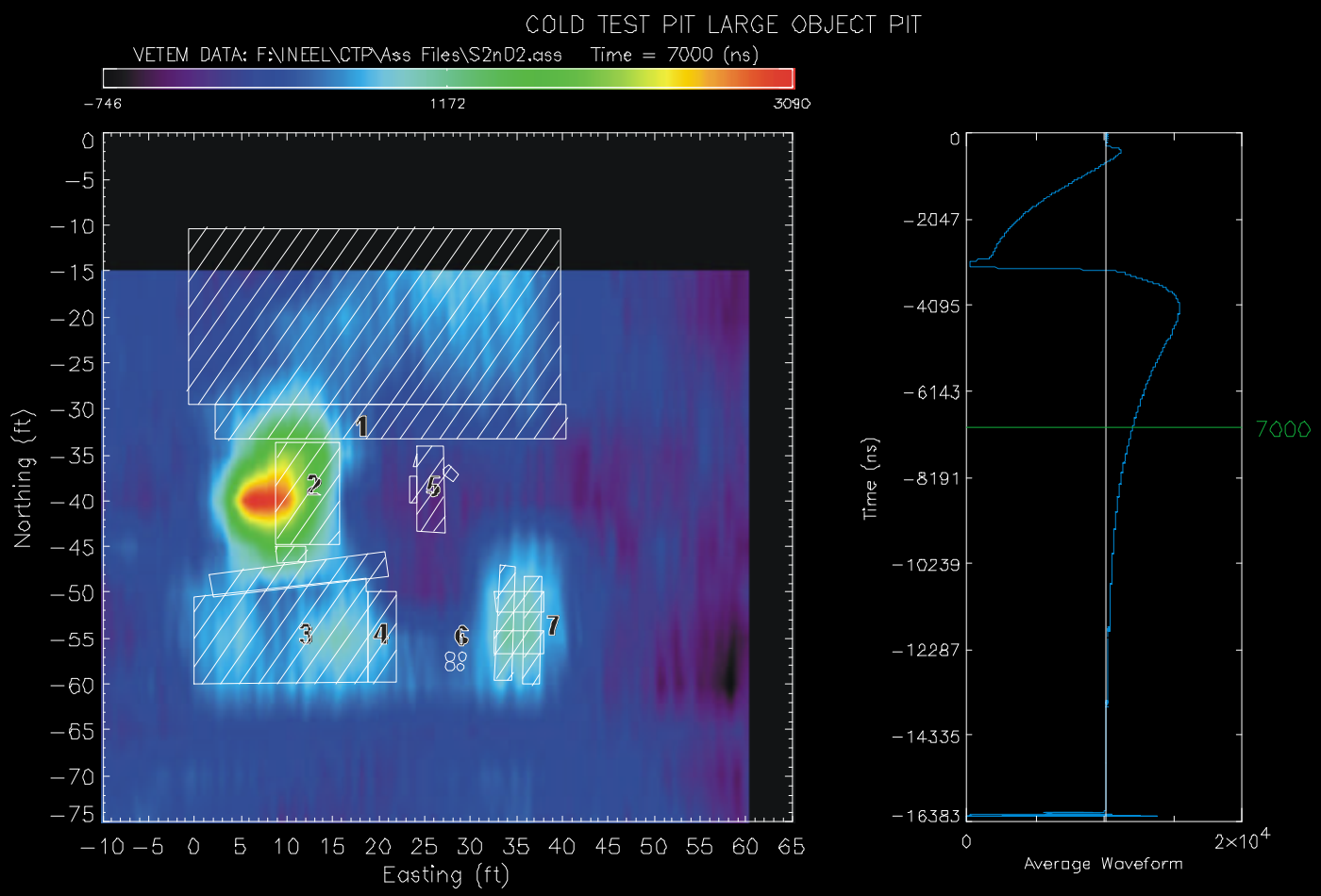

COLD TEST PIT LARGE OBJECT PIT
VETEM DATA: F:\INEEL\CTP\Ass Files\S2n02.ass Time = 5250 (ns)
-1268
2720
6710
Northing (ft)
Easting (ft)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
-65
-70
-75
-10 -5 0 5 10 15 20 25 30 35 40 45 50 55 60 65
1
2
3
4
5
6
7
Time (ns)
0
-2047
-4095
-6143
-8191
-10239
-12287
-14335
-16383
5250
0
2x10^4
Average Waveform

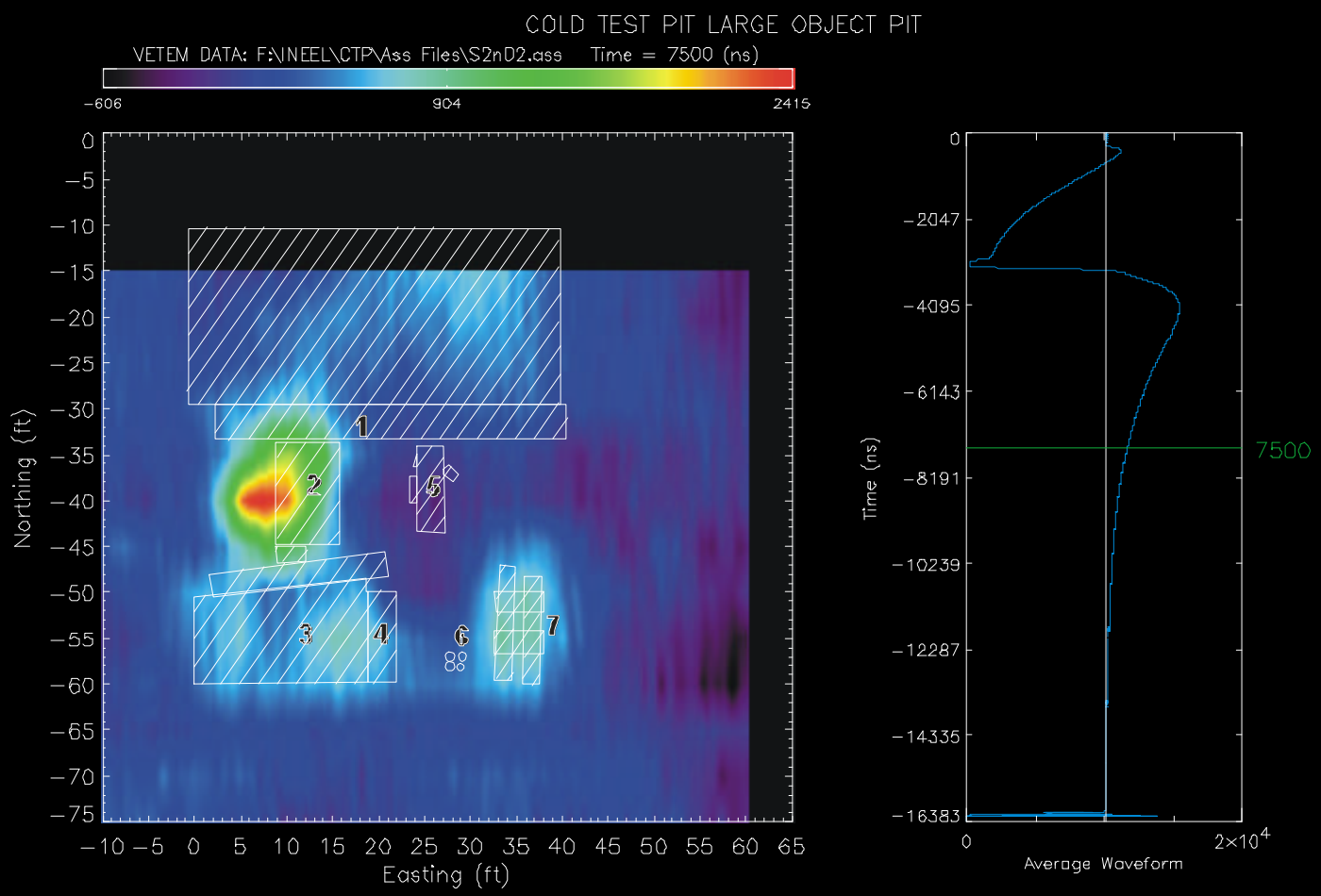

COLD TEST PIT LARGE OBJECT PIT
VETEM DATA: F:\INEEL\CTP\Ass Files\S2n02.ass Time = 5500 (ns)
−1138
2473
6085
Northing (ft)
0
−5
−10
−15
−20
−25
−30
−35
−40
−45
−50
−55
−60
−65
−70
−75
−10 −5 0 5 10 15 20 25 30 35 40 45 50 55 60 65
Easting (ft)
1
2
3
4
5
6
7
Time (ns)
0
−2047
−4095
−6143
−8191
−10239
−12287
−14335
−16383
5500
0
2×10^4
Average Waveform

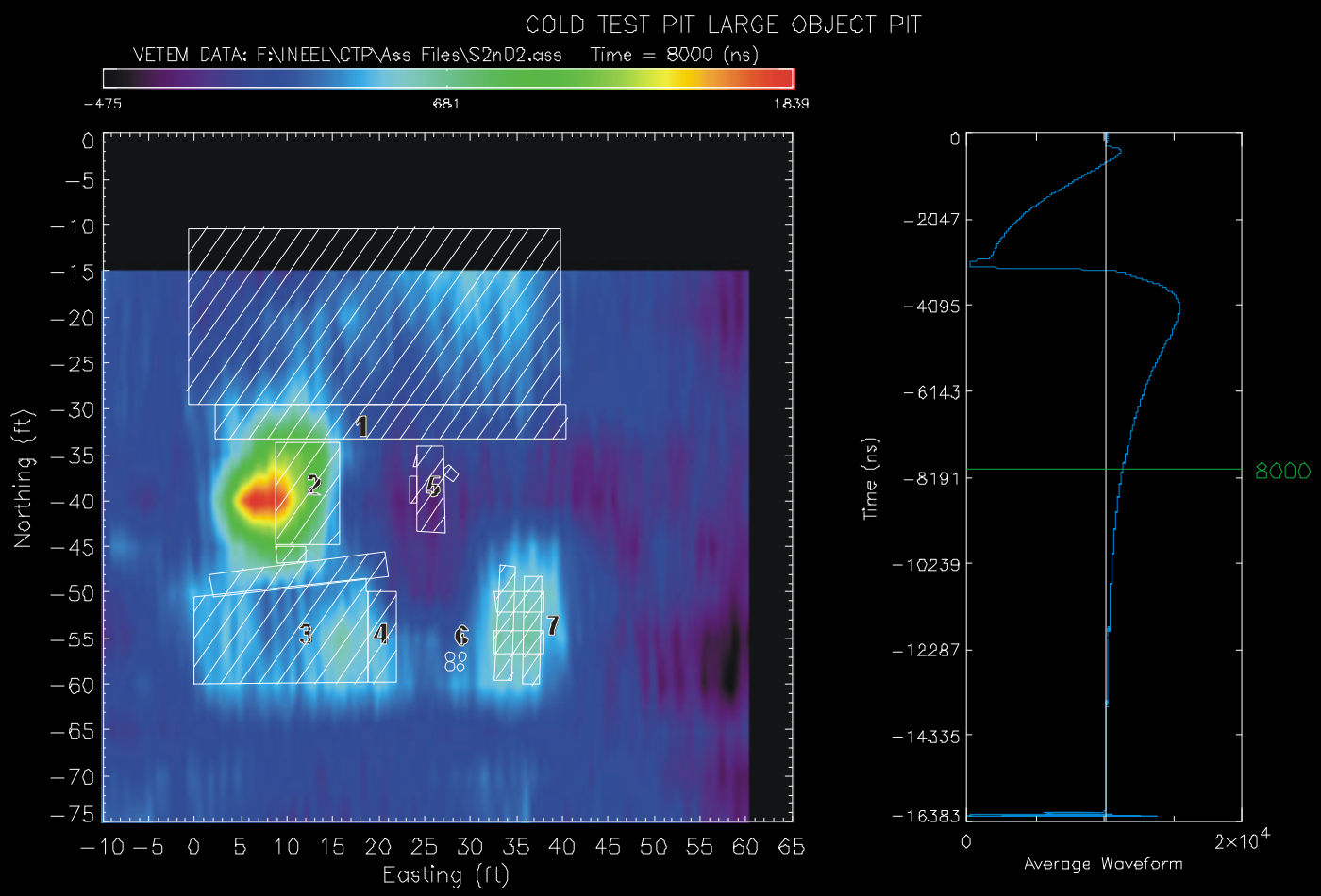

COLD TEST PIT LARGE OBJECT PIT
VETEM DATA: F:\INEEL\CTP\Ass Files\S2n02.ass Time = 5750 (ns)
-1001
2239
5480
Northing (ft)
Easting (ft)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
-65
-70
-75
-10 -5 0 5 10 15 20 25 30 35 40 45 50 55 60 65
1
2
3
4
5
6
7
Time (ns)
0
-2047
-4095
-6143
-8191
-10239
-12287
-14335
-16383
5750
0
2x10^4
Average Waveform

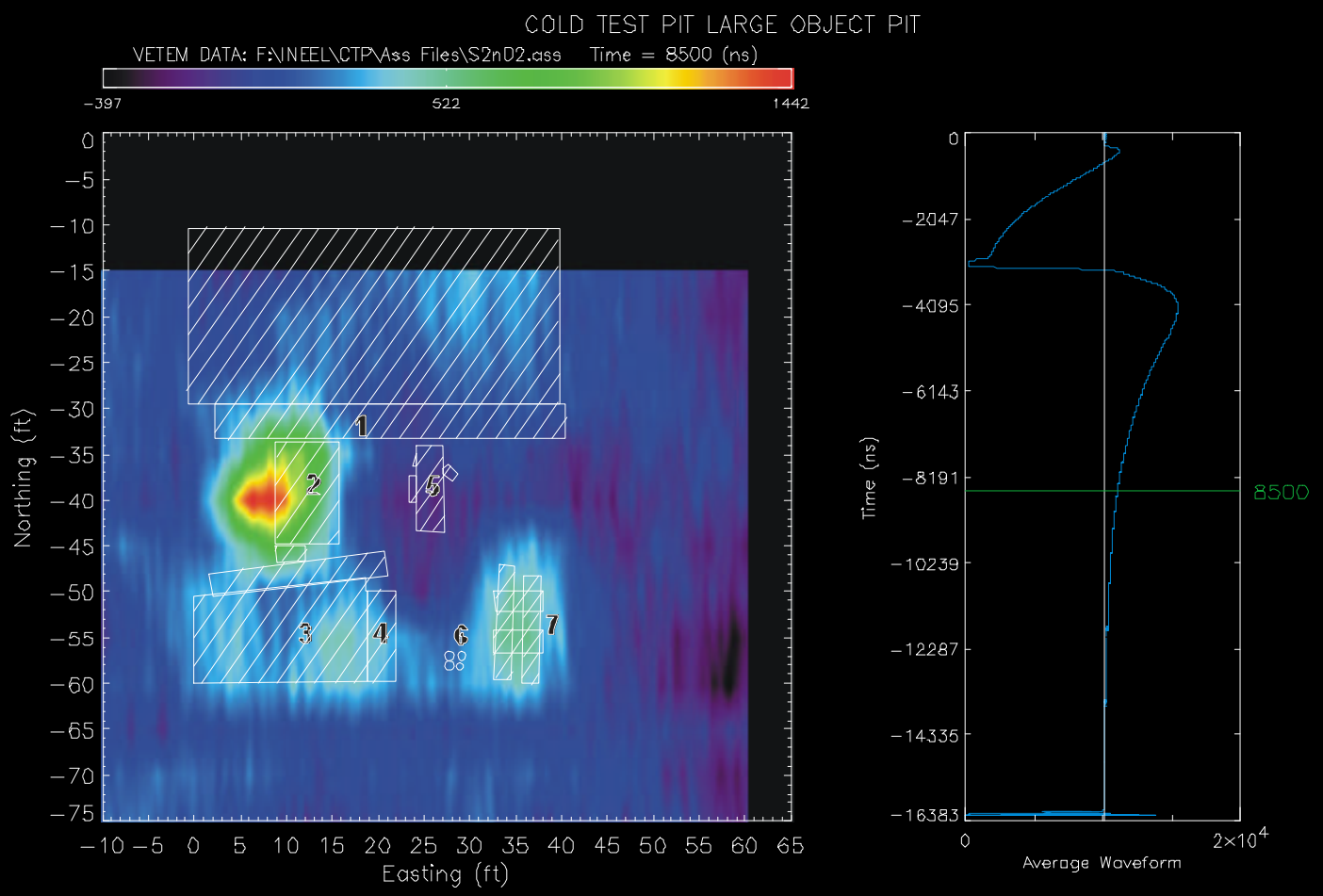

COLD TEST PIT LARGE OBJECT PIT
VETEM DATA: F:\INEEL\CTP\Ass Files\S2n02.ass Time = 6000 (ns)
-997
1951
4900
Northing (ft)
Easting (ft)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
-65
-70
-75
-10 -5 0 5 10 15 20 25 30 35 40 45 50 55 60 65
1
2
3
4
5
6
7
Time (ns)
0
-2047
-4095
-6143
-8191
-10239
-12287
-14335
-16383
6000
0
2x10^4
Average Waveform

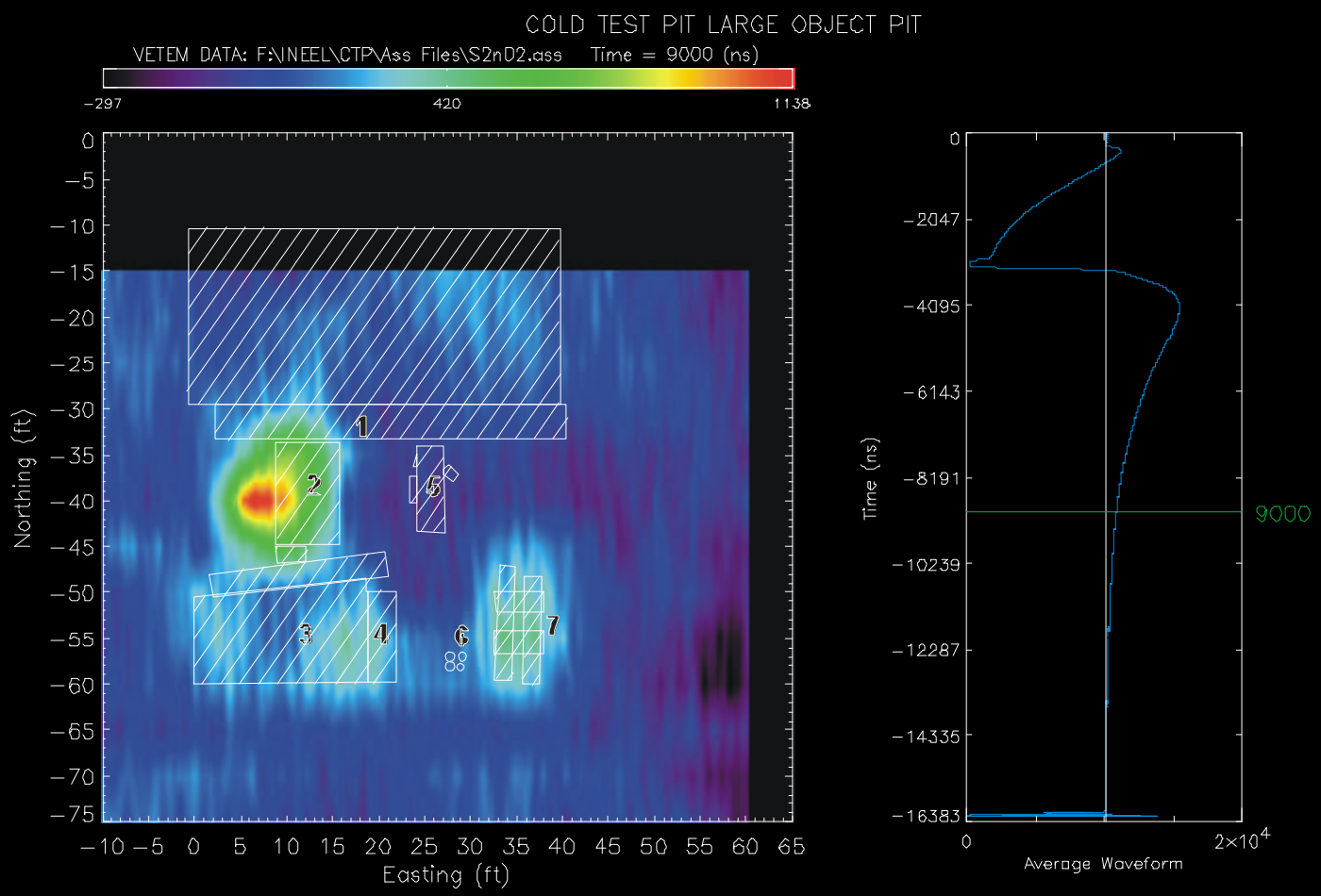

COLD TEST PIT LARGE OBJECT PIT
VETEM DATA: F:\INEEL\CTP\Ass Files\S2n02.ass Time = 6500 (ns)
-789
1549
3888
Northing (ft)
Easting (ft)
1
2
3
4
5
6
7
Time (ns)
Average Waveform
6500

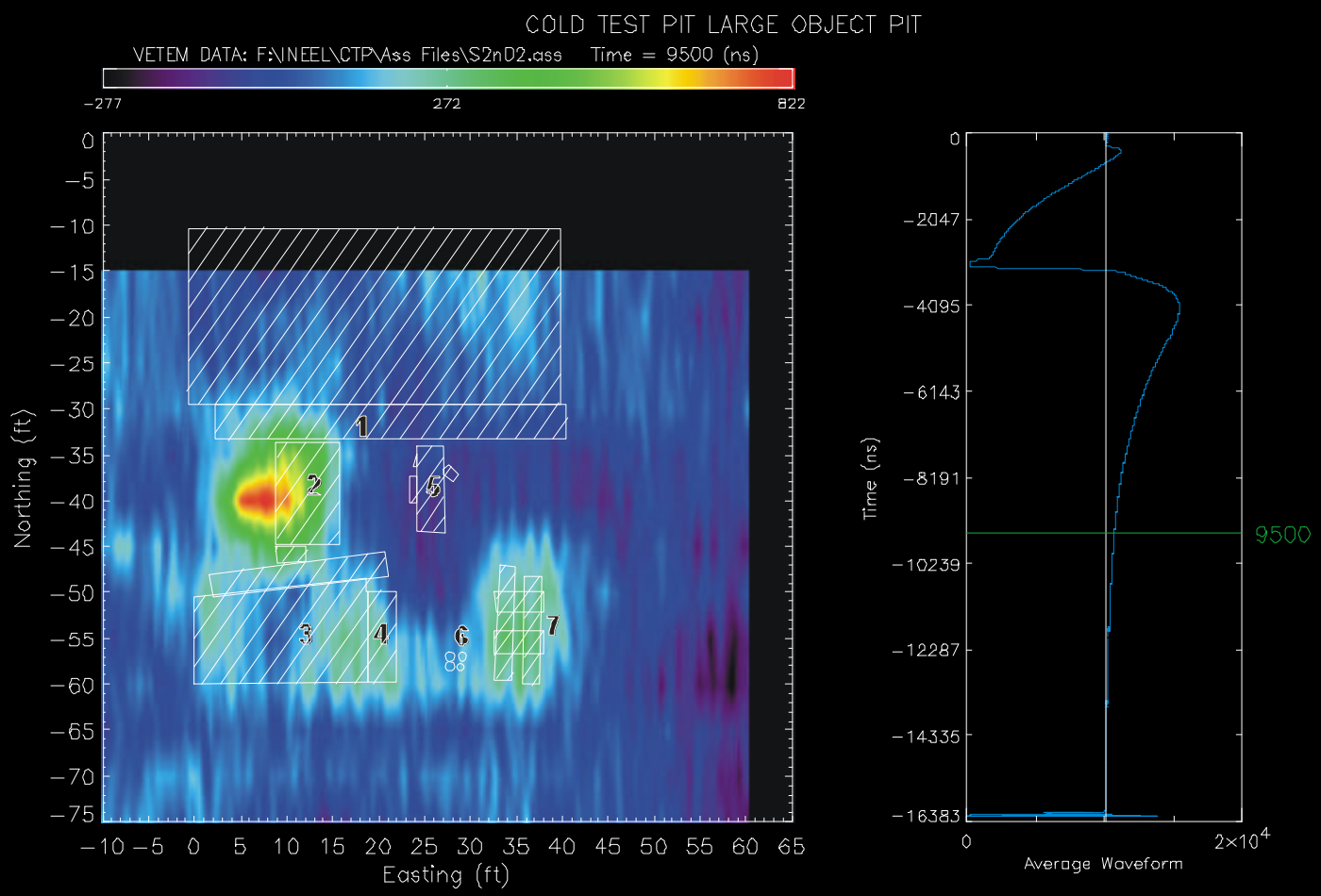

COLD TEST PIT LARGE OBJECT PIT
VETEM DATA: F:\INEEL\CTP\Ass Files\S2n02.ass Time = 7000 (ns)
-746
1172
3090
Northing (ft)
Easting (ft)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
-65
-70
-75
-10 -5 0 5 10 15 20 25 30 35 40 45 50 55 60 65
1
2
3
4
5
6
7
Time (ns)
0
-2047
-4095
-6143
-8191
-10239
-12287
-14335
-16383
7000
0
2x10^4
Average Waveform

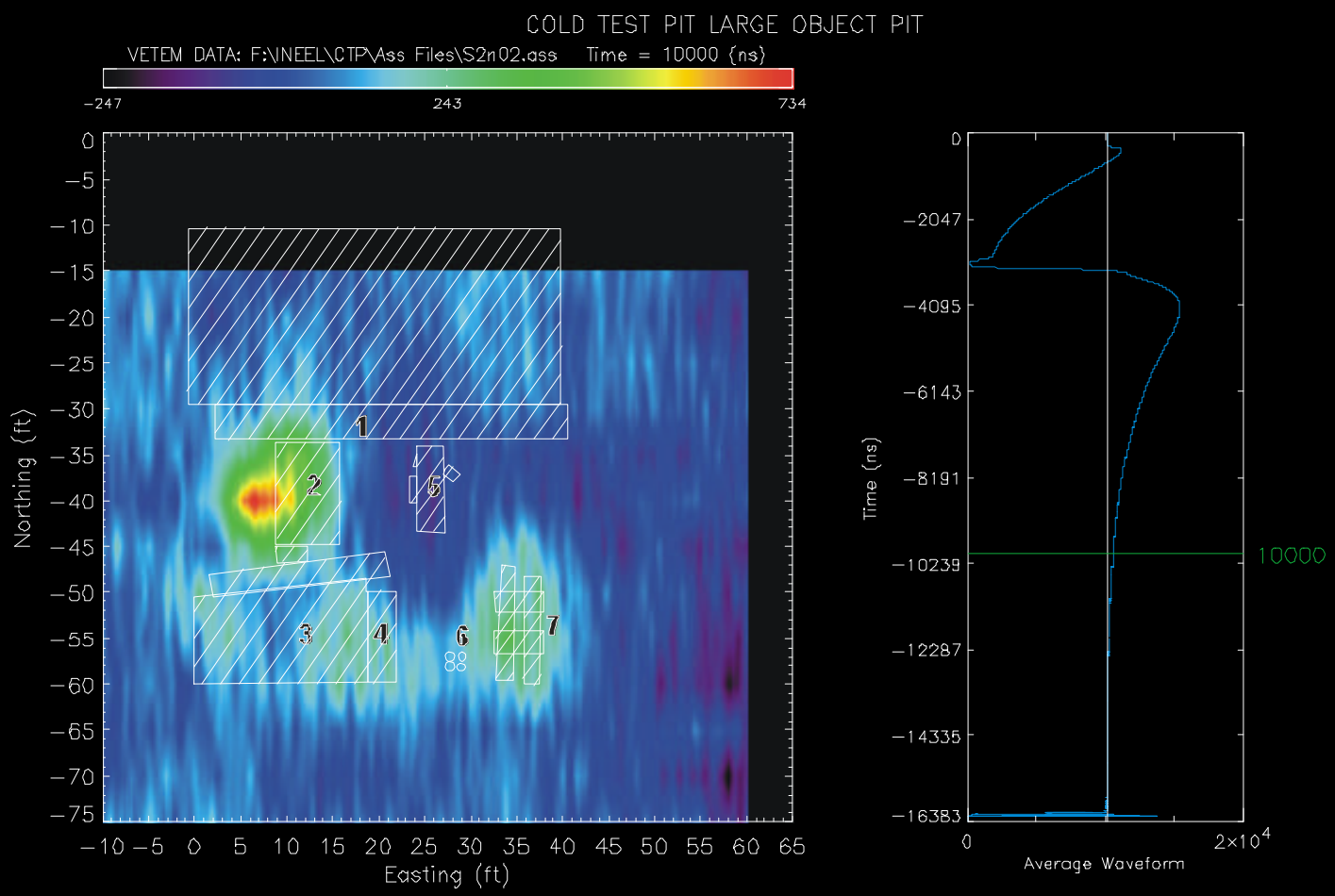

COLD TEST PIT LARGE OBJECT PIT
VETEM DATA: F:\INEEL\CTP\Ass Files\S2n02.ass Time = 7500 (ns)
-606
904
2415
Northing (ft)
Easting (ft)
1
2
3
4
5
6
7
Time (ns)
7500
Average Waveform

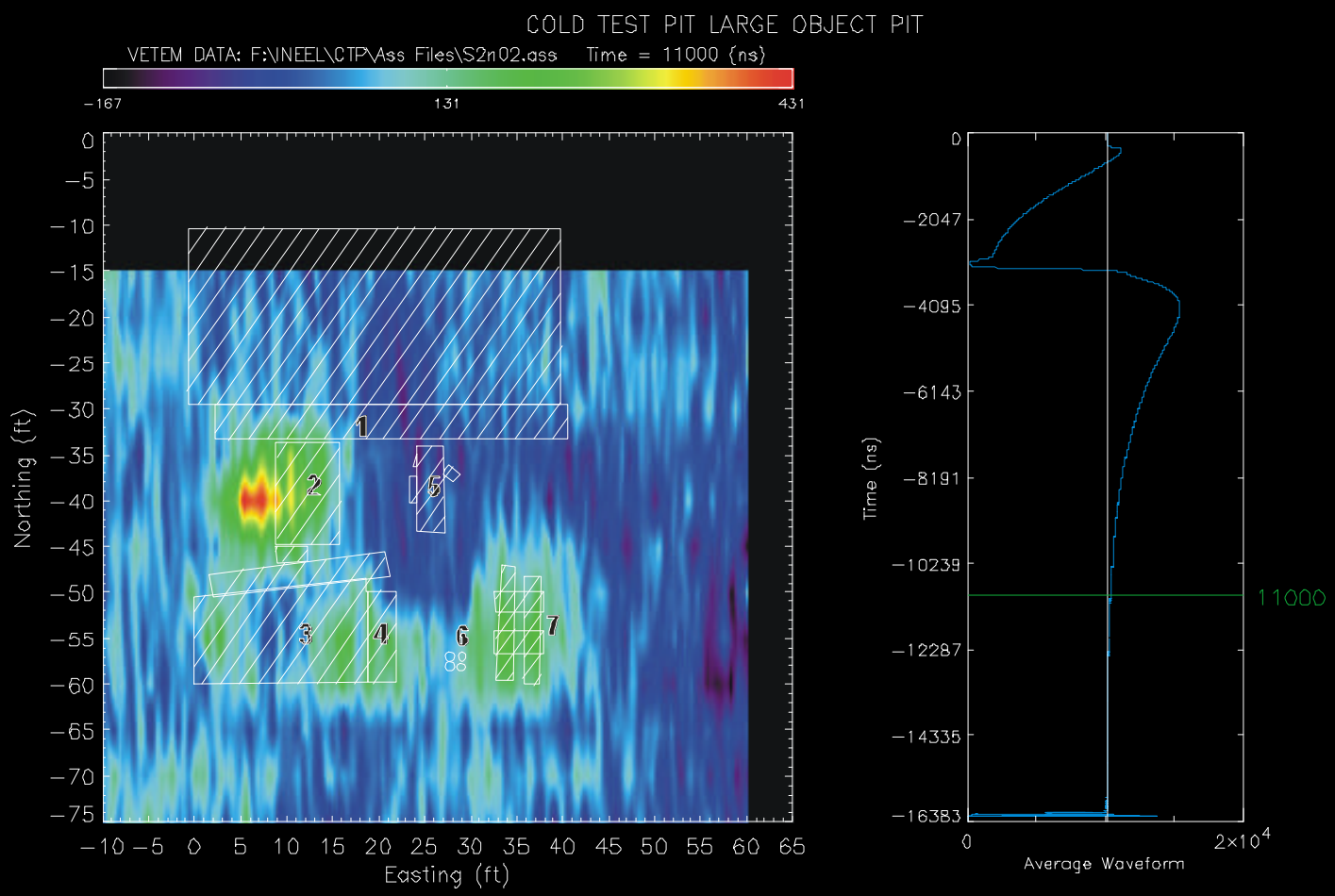

COLD TEST PIT LARGE OBJECT PIT
VETEM DATA: F:\INEEL\CTP\Ass Files\S2n02.ass Time = 8000 (ns)
-475
681
1839
Northing (ft)
Easting (ft)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
-65
-70
-75
-10 -5 0 5 10 15 20 25 30 35 40 45 50 55 60 65
1
2
3
4
5
6
7
Time (ns)
0
-2047
-4095
-6143
-8191
-10239
-12287
-14335
-16383
8000
0
2x10^4
Average Waveform

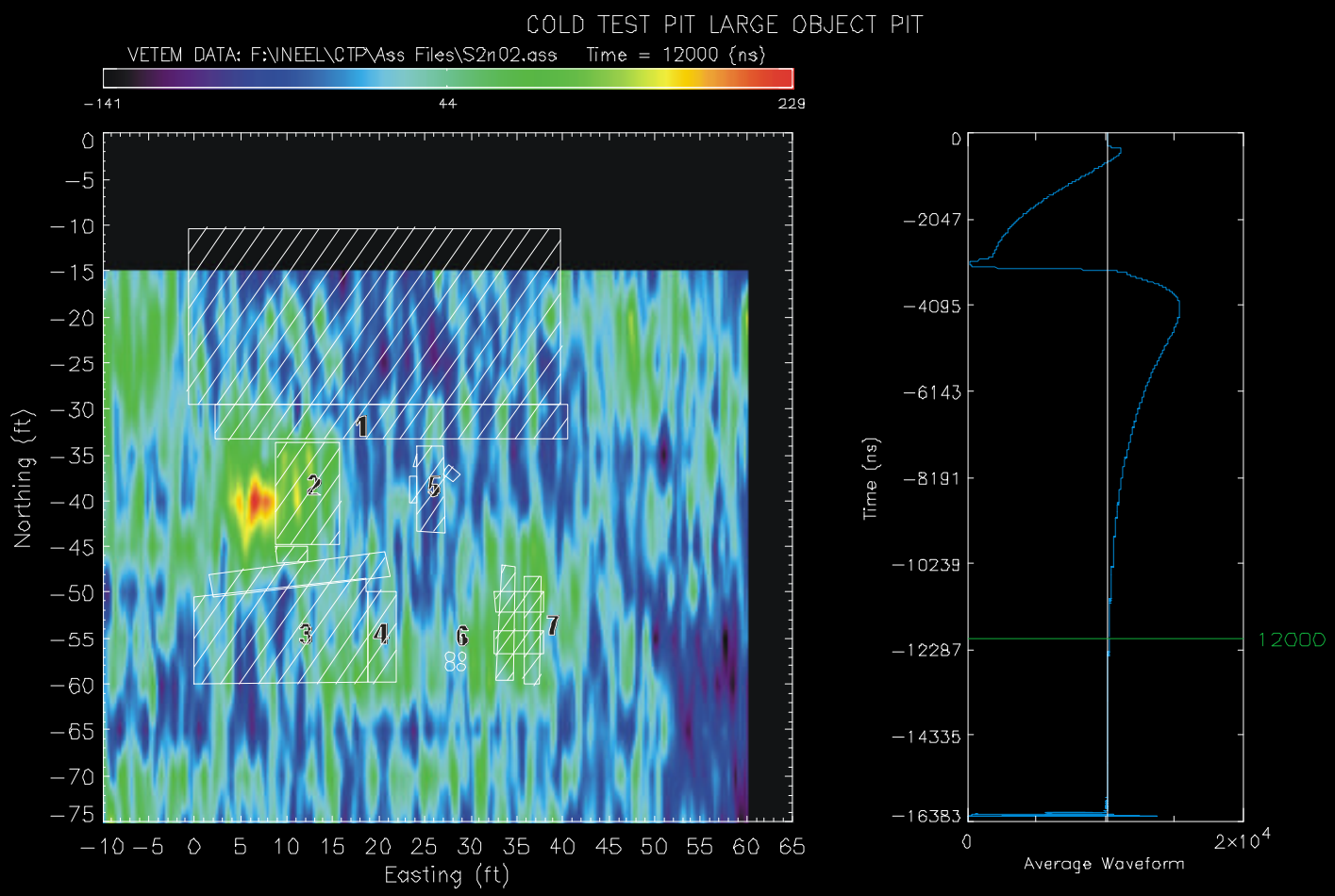

COLD TEST PIT LARGE OBJECT PIT
VETEM DATA: F:\INEEL\CTP\Ass Files\S2n02.ass Time = 8500 (ns)
-397
522
1442
Northing (ft)
Easting (ft)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
-65
-70
-75
-10 -5 0 5 10 15 20 25 30 35 40 45 50 55 60 65
1
2
3
4
5
6
7
Time (ns)
0
-2047
-4095
-6143
-8191
-10239
-12287
-14335
-16383
8500
0
2x10^4
Average Waveform


COLD TEST PIT LARGE OBJECT PIT
VETEM DATA: F:\INEEL\CTP\Ass Files\S2n02.ass Time = 9000 (ns)
-297
420
1138
Northing (ft)
Easting (ft)
1
2
3
4
5
6
7
Time (ns)
9000
Average Waveform

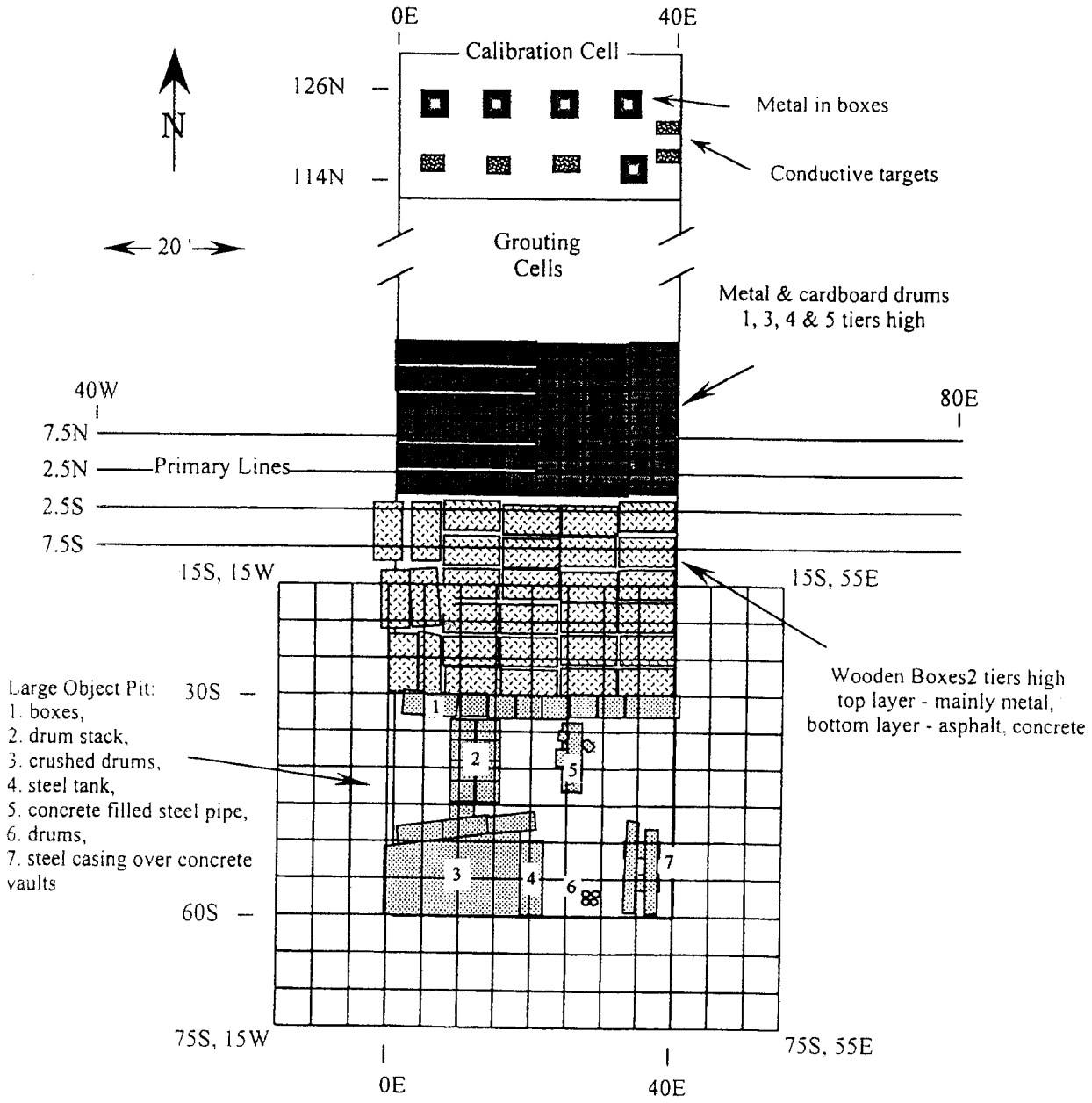

COLD TEST PIT LARGE OBJECT PIT
VETEM DATA: F:\INEEL\CTP\Ass Files\S2n02.ass Time = 9500 (ns)
-277
272
822
Northing (ft)
Easting (ft)
1
2
3
4
5
6
7
Time (ns)
9500
Average Waveform


COLD TEST PIT LARGE OBJECT PIT
VETEM DATA: F:\INEEL\CTP\Ass Files\S2n02.ass Time = 10000 {ns}
-247
243
734
Northing (ft)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
-65
-70
-75
-10 -5 0 5 10 15 20 25 30 35 40 45 50 55 60 65
Easting (ft)
1
2
3
4
5
6
7
Time (ns)
0
-2047
-4095
-6143
-8191
-10239
-12287
-14335
-16383
10000
0
2×10^4
Average Waveform

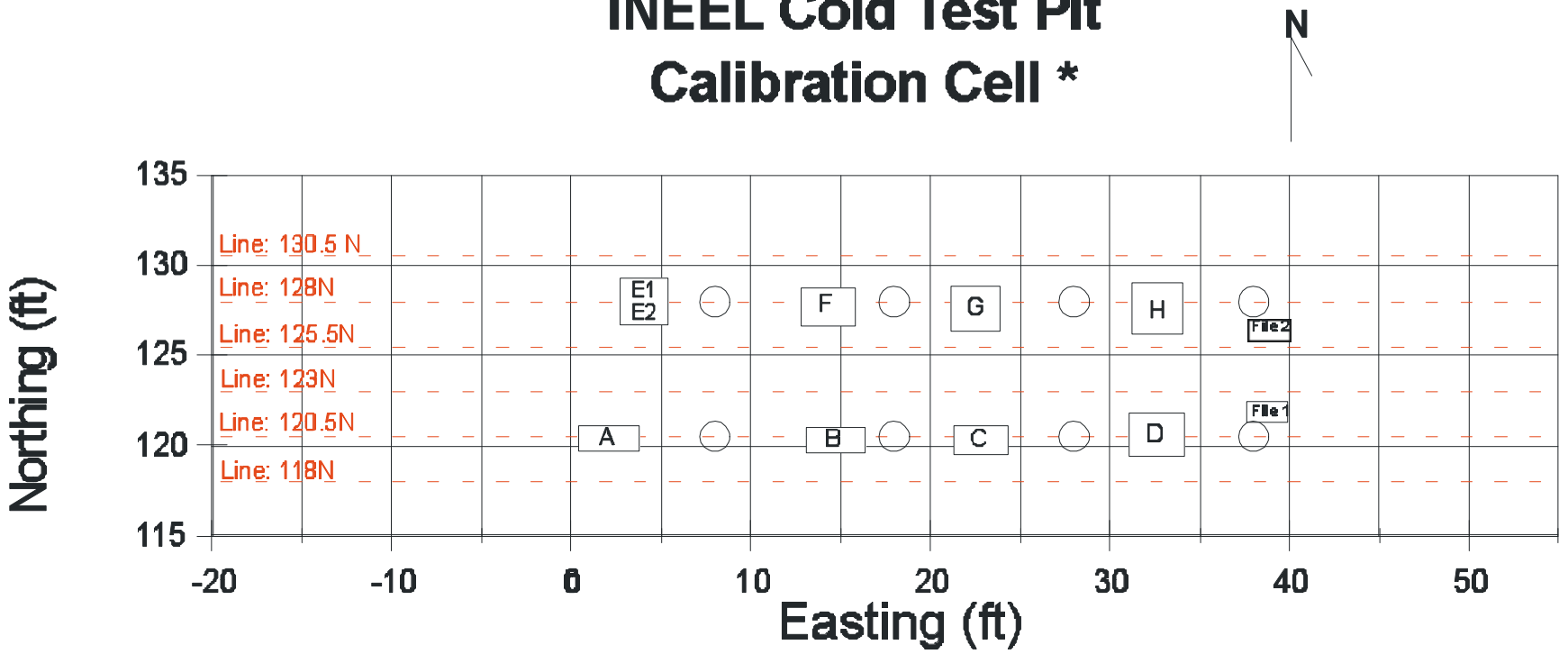

COLD TEST PIT LARGE OBJECT PIT
VETEM DATA: F:\INEEL\CTP\Ass Files\S2n02.ass Time = 11000 {ns}
-167
131
431
Northing (ft)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
-65
-70
-75
-10 -5 0 5 10 15 20 25 30 35 40 45 50 55 60 65
Easting (ft)
1
2
3
4
5
6
7
Time (ns)
0
-2047
-4095
-6143
-8191
-10239
-12287
-14335
-16383
11000
0
2×10^4
Average Waveform


COLD TEST PIT LARGE OBJECT PIT
VETEM DATA: F:\INEEL\CTP\Ass Files\S2n02.ass Time = 12000 {ns}
-141
44
229
Northing (ft)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
-65
-70
-75
-10 -5 0 5 10 15 20 25 30 35 40 45 50 55 60 65
Easting (ft)
1
2
3
4
5
6
7
Time (ns)
0
-2047
-4095
-6143
-8191
-10239
-12287
-14335
-16383
12000
0
2×10^4
Average Waveform

INEEL COLD TEST PIT (CTP)



INEEL Cold Test Pit
Calibration Cell *



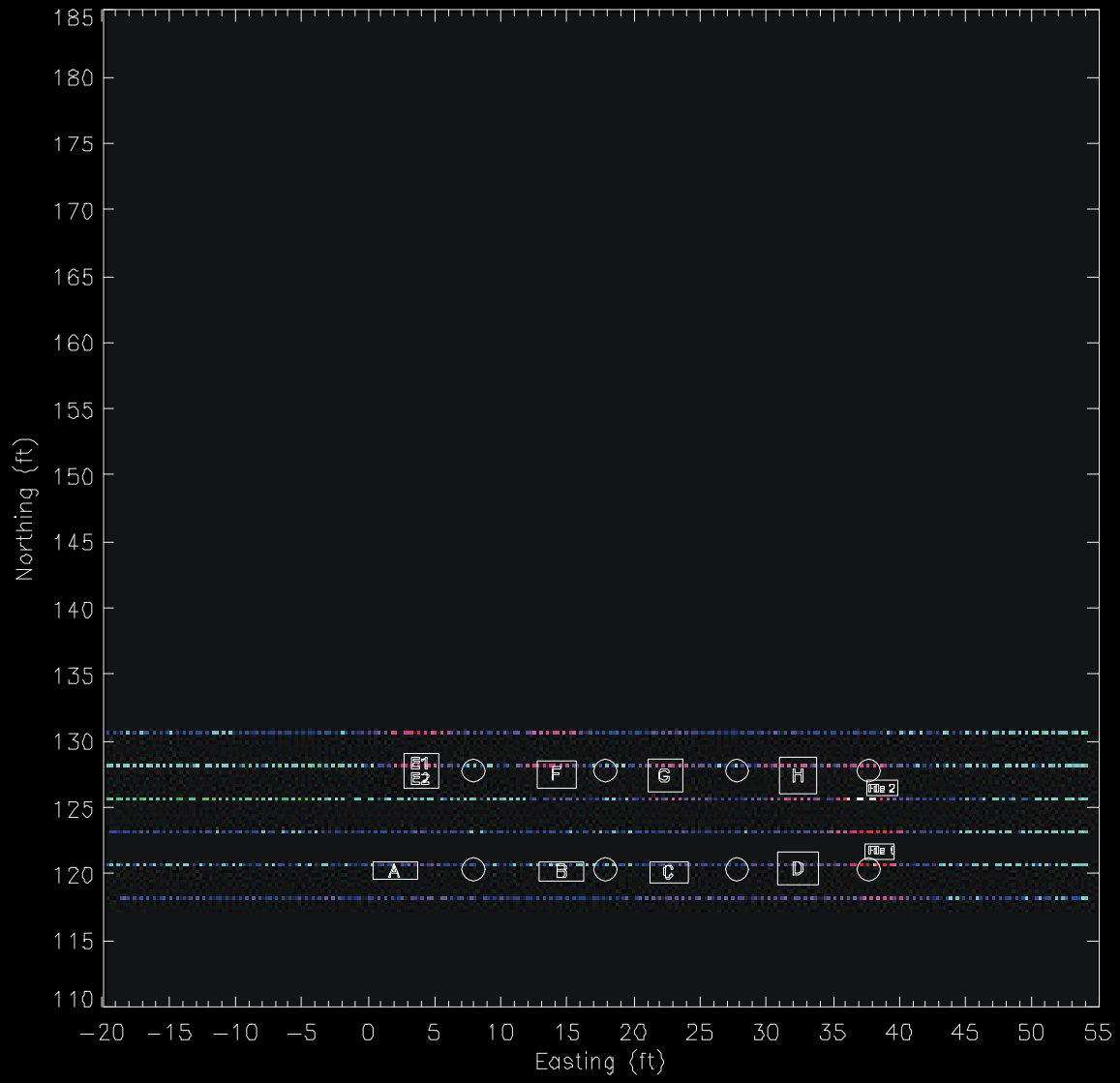
Item ID	Waste form type	Dimensions	Contents
A	Drum w/liner (55 gal)	24 in. dia. x 36 in.	Concrete
B	Plastic drum (30 gal)	18 in. dia. X 29 in.	Salt water
C	Drum w/liner (55 gal)	24 in. dia. x 36 in.	Foam
D	Wood box	2 x 4 x 4 ft.	Wood and Paper
E	Wood boxes (2, stacked)	2 x 4 x 4 ft. (each)	E1=Wood and Paper E2=Ferrous metals
F	Wood box	2 x 4 x 4 ft.	Mixed metals
G	Wood box	2 x 4 x 4 ft.	Nonferrous metals
H	Wood box	2 x 4 x 4 ft.	Dense-pack metal
File 1	Five-drawer metal file cabinet	14 x 28 x 57 in.	Empty
File 2	Five-drawer metal file cabinet	14 x 28 x 57 in.	Empty

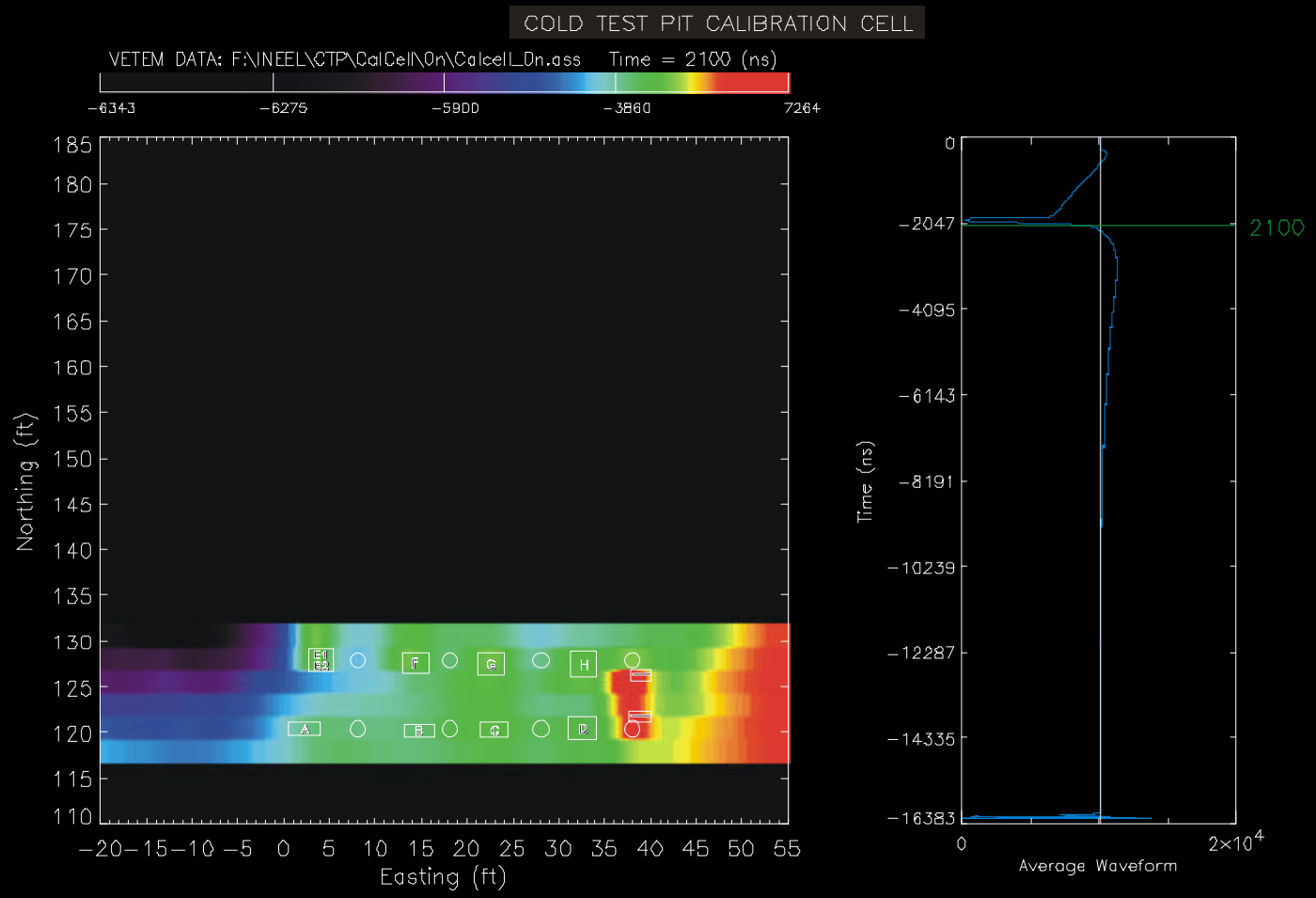
* Based on EG&G Idaho, Inc. FORM EGG-2631/(Rev. 01-92)

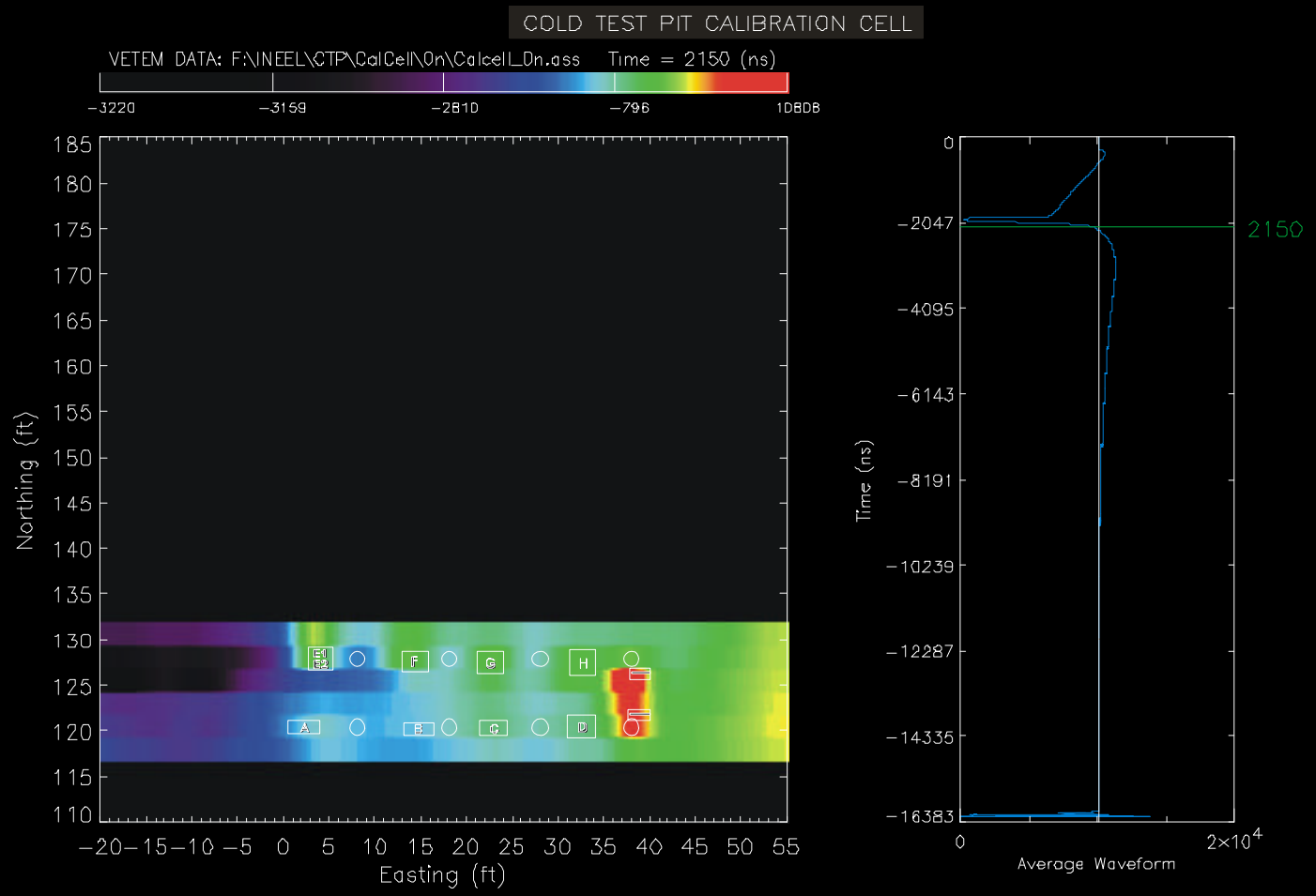
Comments on Calibration Cell results

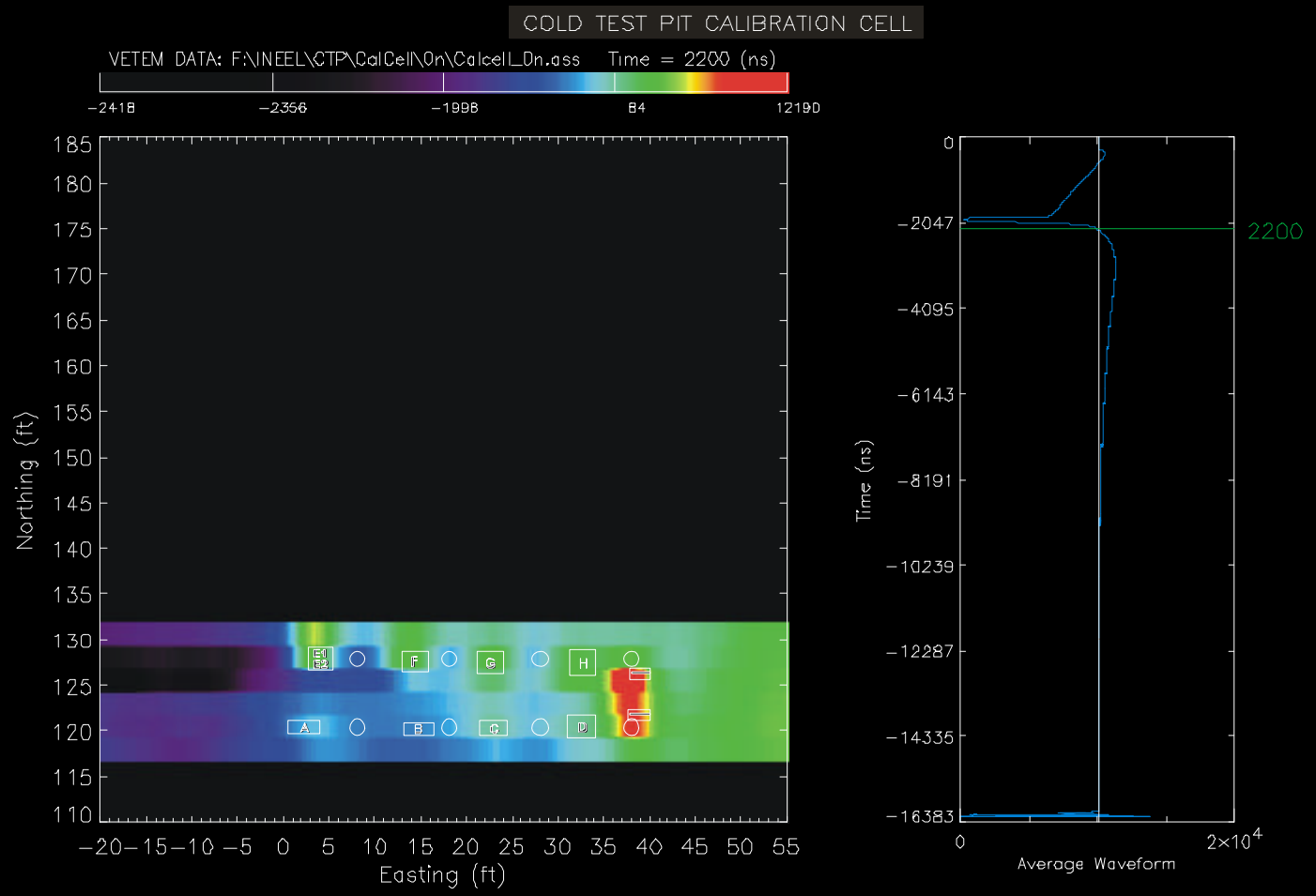
- Used only the overlapped antennas during this test.
- In this case we start after Tx turnoff, so no color inversion.
- Note that at early times there is an indication of an apparent high conductivity region at the eastern end. This dies out at later times while responses to metal buried targets persist. This early time response appears to be geologic in origin.
- Strongest responses from buried file cabinets. Responses appear merged at early time but separate at later times.

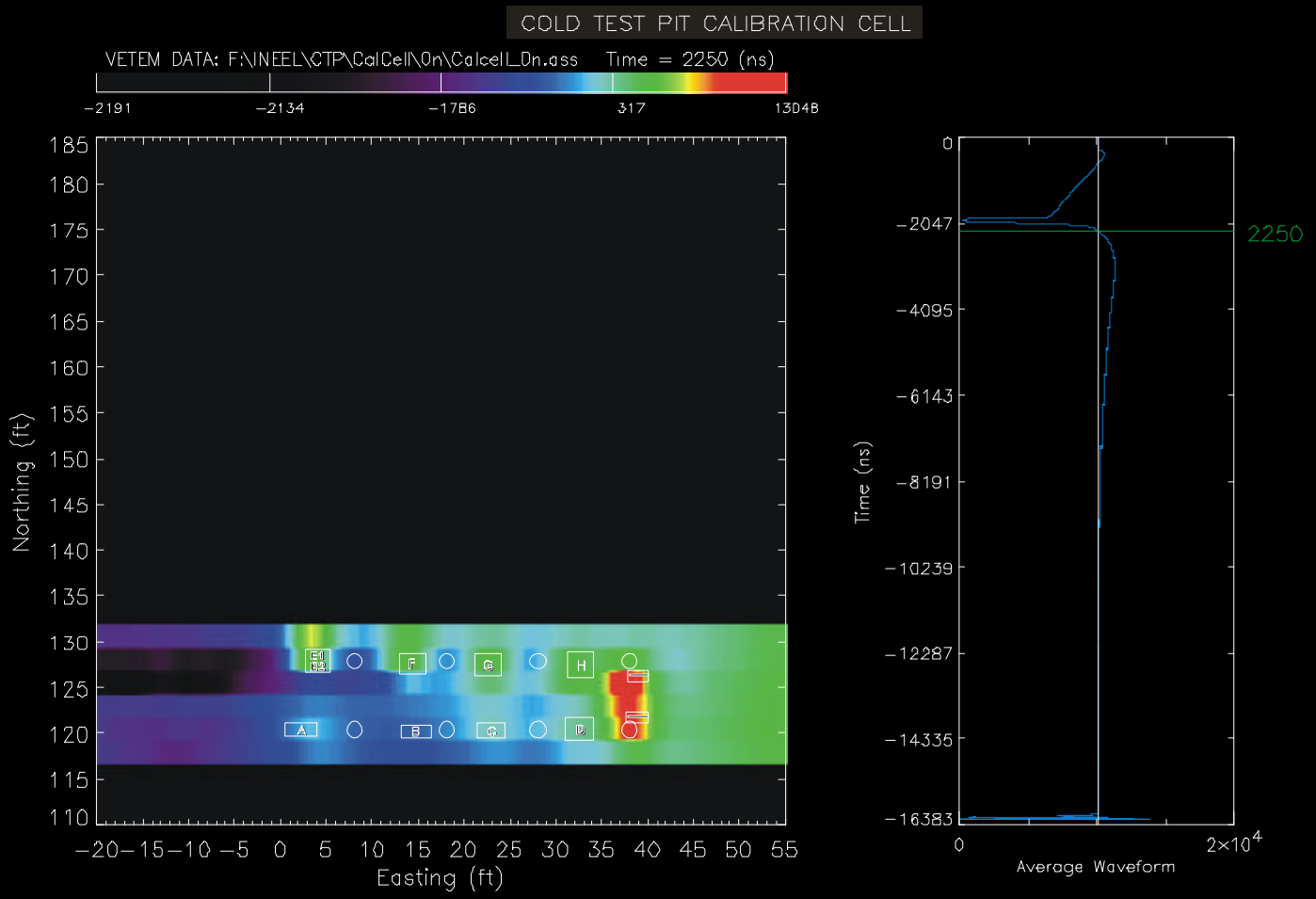
Cold Test Pit
Calibration Cell
Traverse Lines

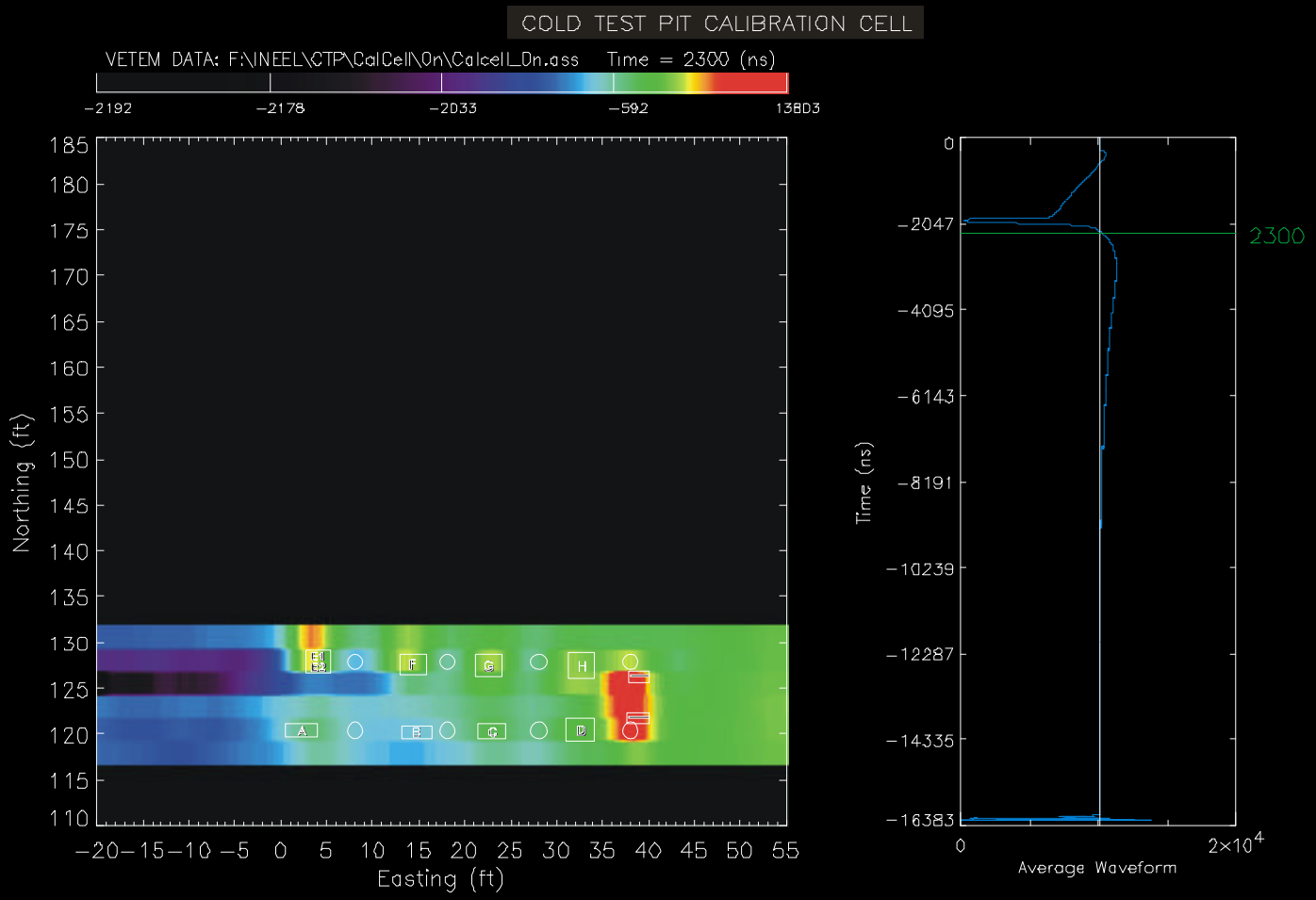


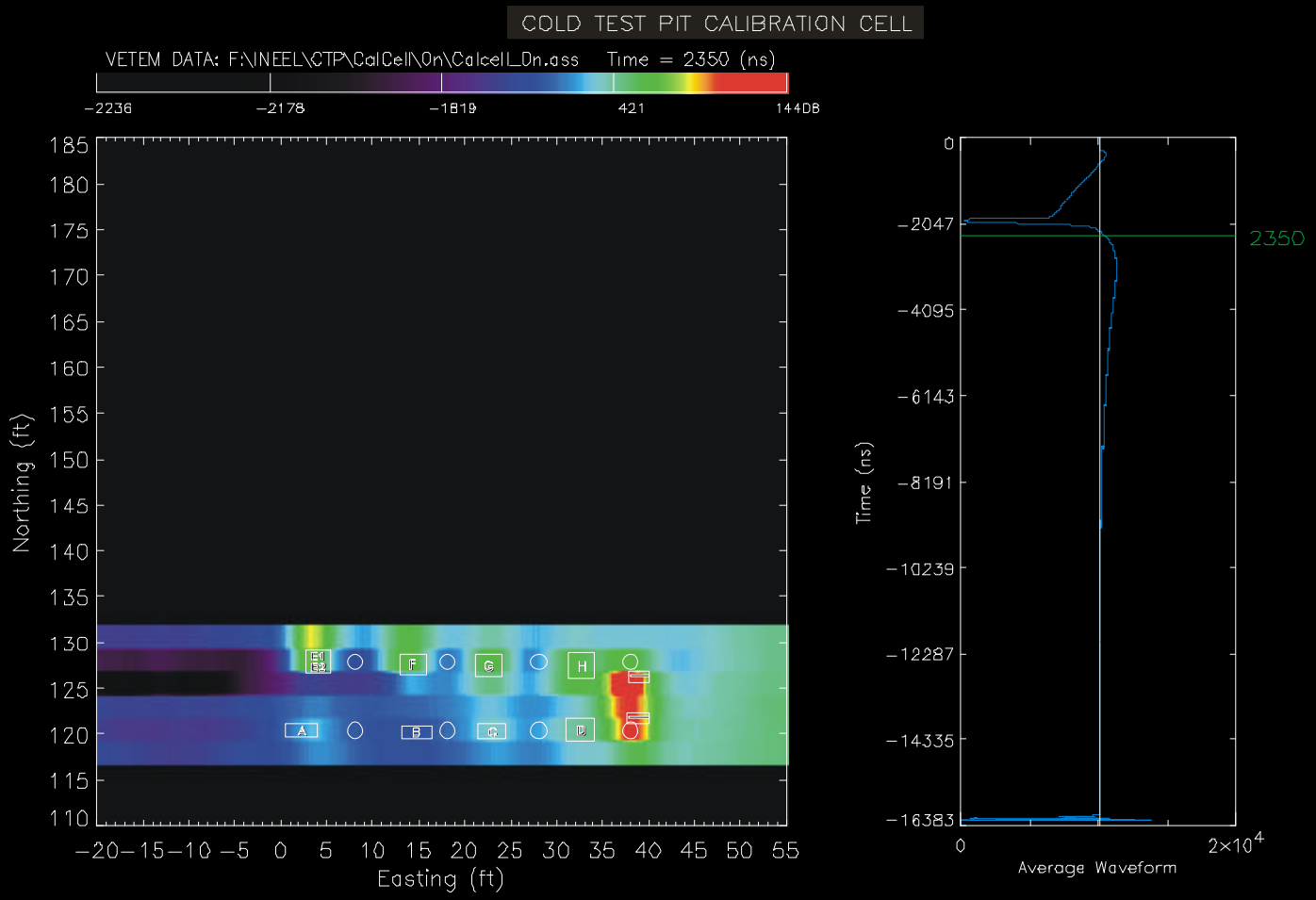

COLD TEST PIT CALIBRATION CELL
VETEM DATA: F:\INEEL\CTP\CalCell\On\CalcelI_On.ass Time = 2100 (ns)
-6343
-6275
-5900
-3860
7264
Northing (ft)
185
180
175
170
165
160
155
150
145
140
135
130
125
120
115
110
-20 -15 -10 -5 0 5 10 15 20 25 30 35 40 45 50 55
Easting (ft)
A
B
C
D
E
F
G
H
Time (ns)
0
-2047
-4095
-6143
-8191
-10239
-12287
-14335
-16383
2100
0
2×10^4
Average Waveform

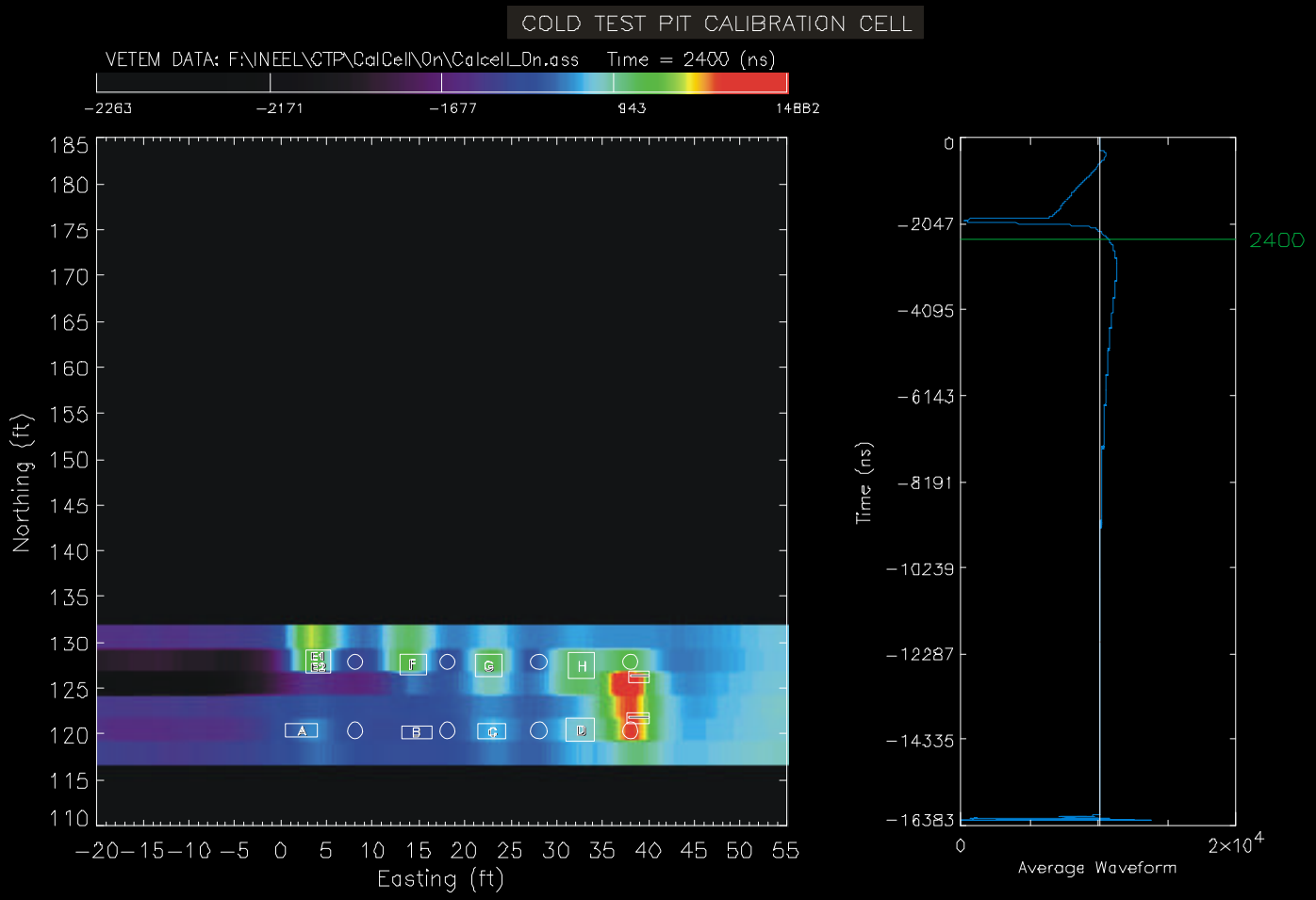

COLD TEST PIT CALIBRATION CELL
VETEM DATA: F:\INEEL\CTP\CalCell\On\CalcelI_On.ass Time = 2150 (ns)
-3220
-3159
-2810
-796
10808
Northing (ft)
Easting (ft)
Time (ns)
Average Waveform
2150
A
B
C
D
E
F
G
H

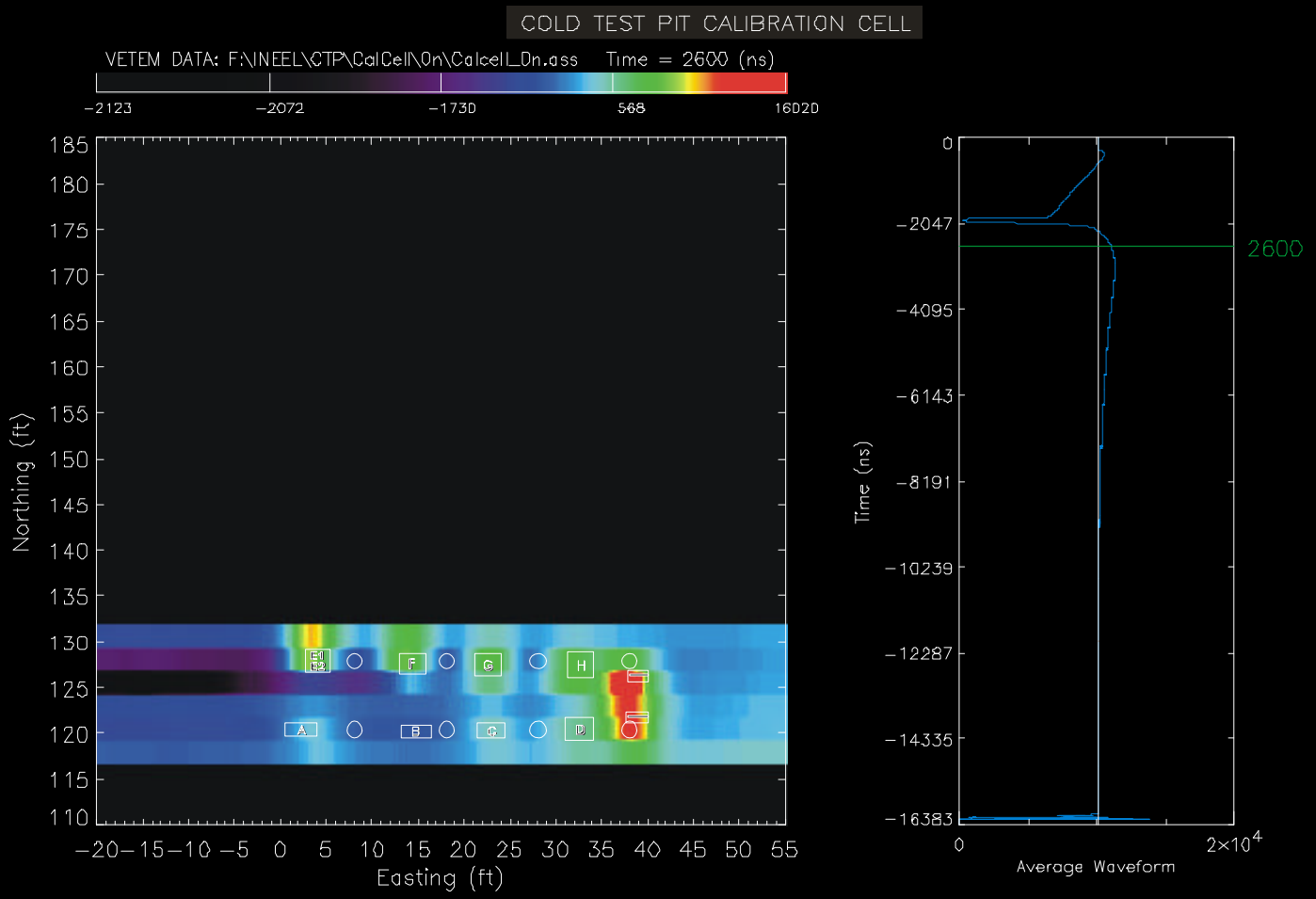

COLD TEST PIT CALIBRATION CELL
VETEM DATA: F:\INEEL\CTP\CalCell\On\CalcellOn.dss Time = 2200 (ns)
-2418
-2356
-1998
84
12190
Northing (ft)
185
180
175
170
165
160
155
150
145
140
135
130
125
120
115
110
-20 -15 -10 -5 0 5 10 15 20 25 30 35 40 45 50 55
Easting (ft)
A
B
C
D
E
F
G
H
0
-2047
-4095
-6143
-8191
-10239
-12287
-14335
-16383
2200
Time (ns)
0
2×10^4
Average Waveform

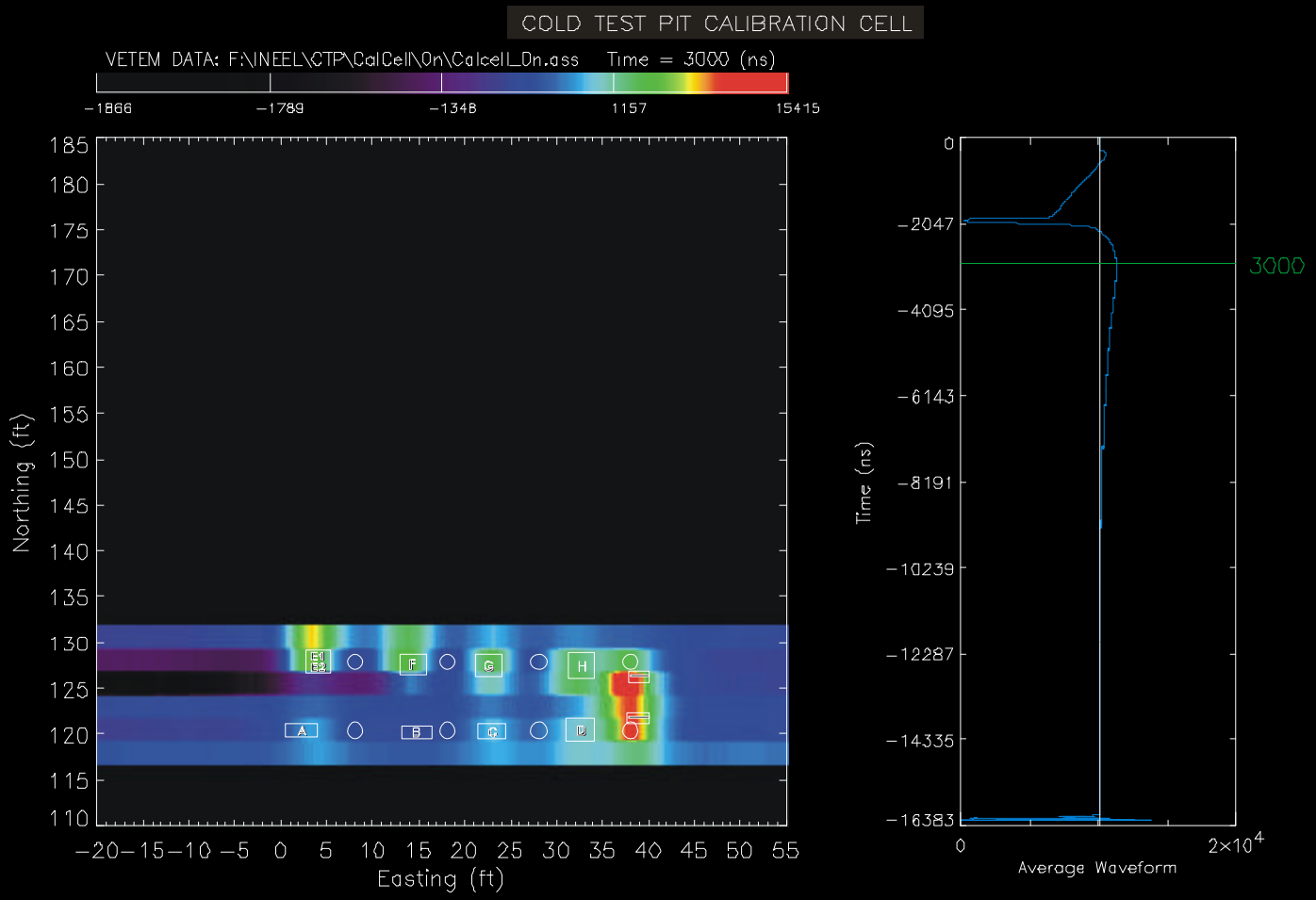

COLD TEST PIT CALIBRATION CELL
VETEM DATA: F:\INEEL\CTP\CalCell\On\CalCell_On.dss Time = 2250 (ns)
−2191
−2134
−1786
317
13048
Northing (ft)
185
180
175
170
165
160
155
150
145
140
135
130
125
120
115
110
−20 −15 −10 −5 0 5 10 15 20 25 30 35 40 45 50 55
Easting (ft)
E1
E2
F
G
H
A
B
C
D
Time (ns)
0
−2047
−4095
−6143
−8191
−10239
−12287
−14335
−16383
2250
0
2×10^4
Average Waveform

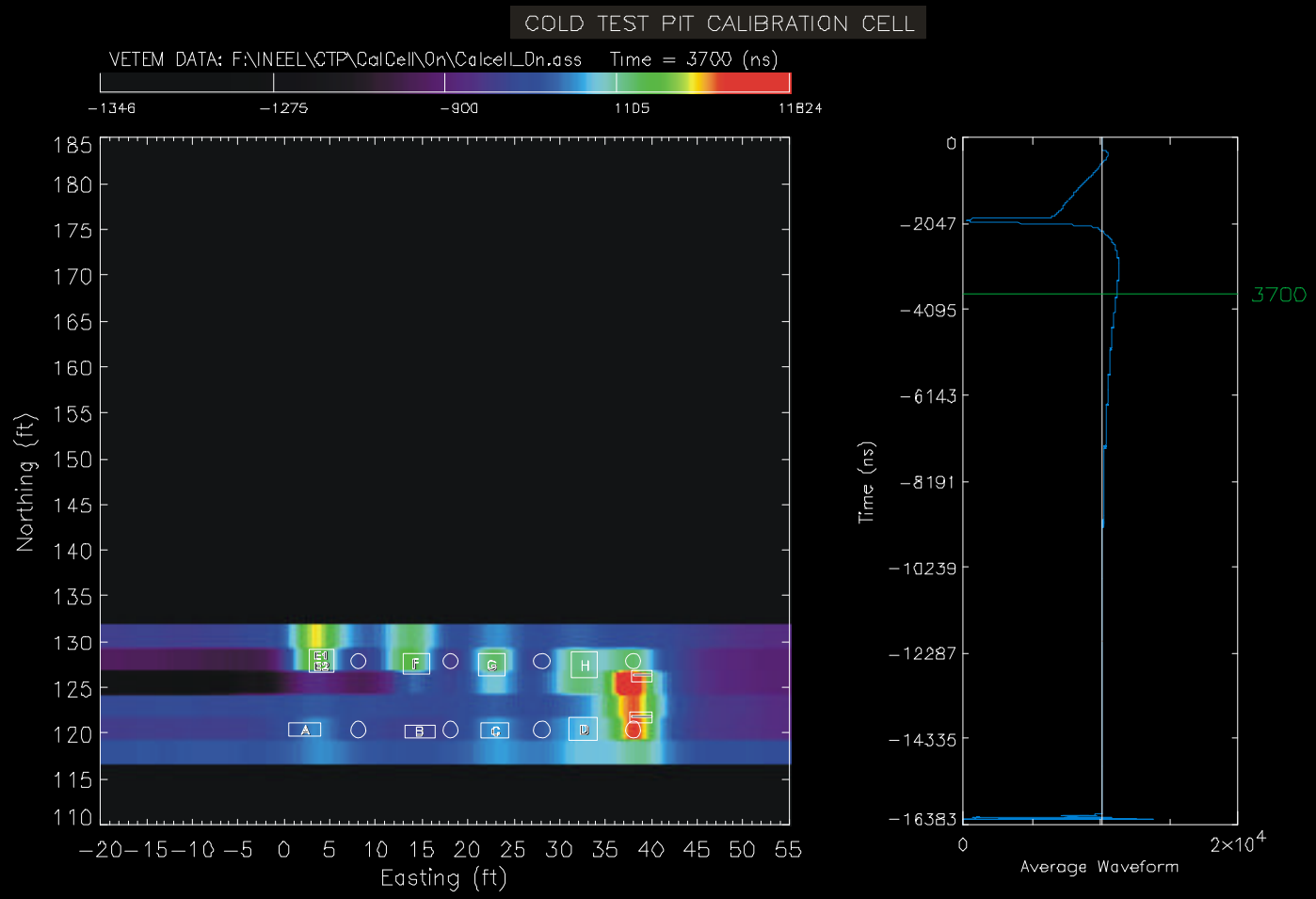

COLD TEST PIT CALIBRATION CELL
VETEM DATA: F:\INEEL\CTP\CalCell\On\CalcellOn.dss Time = 2300 (ns)
−2192
−2178
−2033
−592
13803
Northing (ft)
185
180
175
170
165
160
155
150
145
140
135
130
125
120
115
110
−20 −15 −10 −5 0 5 10 15 20 25 30 35 40 45 50 55
Easting (ft)
A
B
C
D
E
F
G
H
Time (ns)
0
−2047
−4095
−6143
−8191
−10239
−12287
−14335
−16383
2300
0
2×10^4
Average Waveform

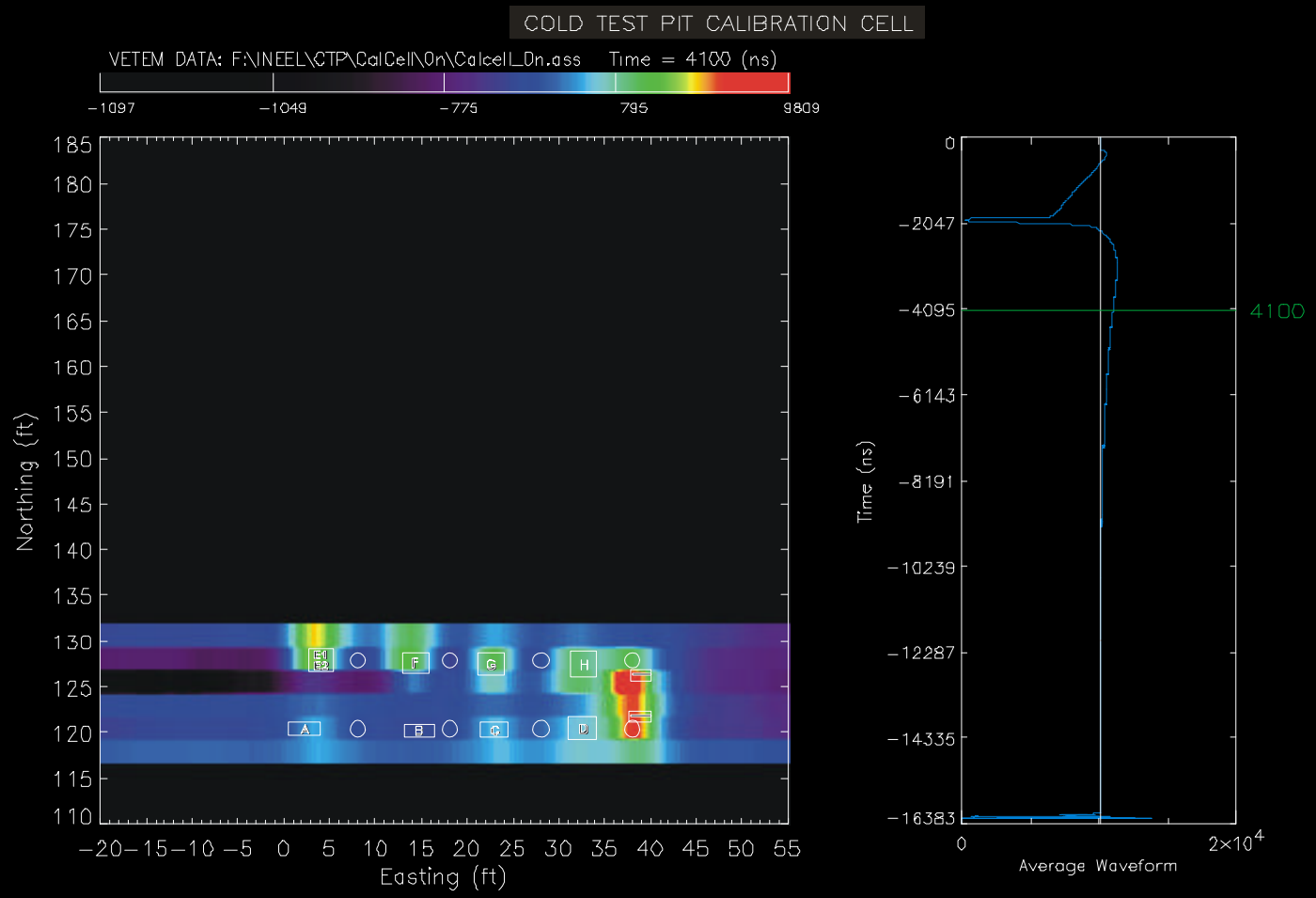

COLD TEST PIT CALIBRATION CELL
VETEM DATA: F:\INEEL\CTP\CalCell\On\CalcellOn.dss Time = 2350 (ns)
-2236
-2178
-1819
421
144DB
Northing (ft)
185
180
175
170
165
160
155
150
145
140
135
130
125
120
115
110
-20 -15 -10 -5 0 5 10 15 20 25 30 35 40 45 50 55
Easting (ft)
A
B
C
D
E1
E2
F
G
H
Time (ns)
0
-2047
-4095
-6143
-8191
-10239
-12287
-14335
-16383
2350
0
2x10^4
Average Waveform

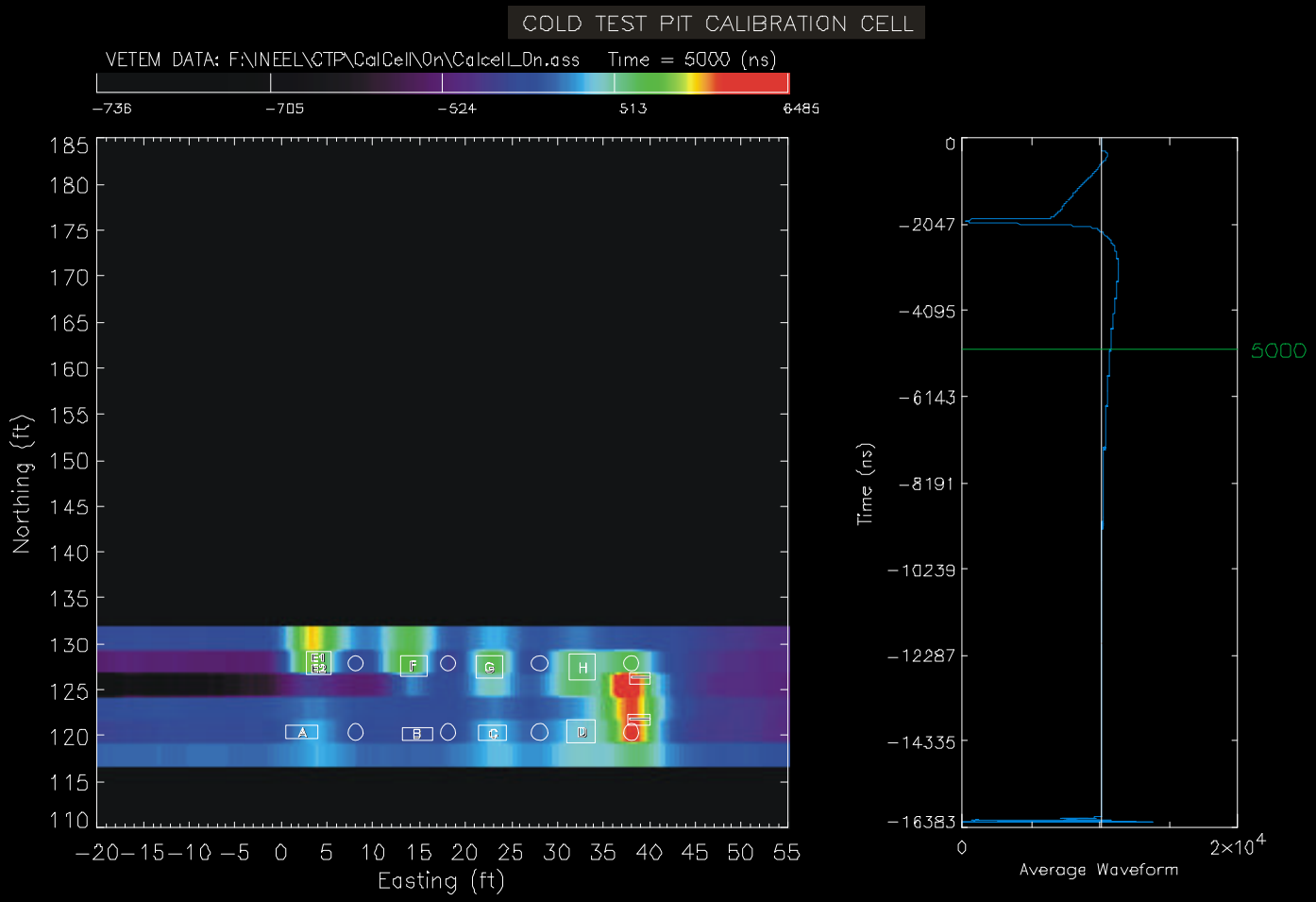

COLD TEST PIT CALIBRATION CELL
VETEM DATA: F:\INEEL\CTP\CalCell\On\CalcellOn.dss Time = 2400 (ns)
−2263
−2171
−1677
943
14882
Northing (ft)
185
180
175
170
165
160
155
150
145
140
135
130
125
120
115
110
−20 −15 −10 −5 0 5 10 15 20 25 30 35 40 45 50 55
Easting (ft)
A
B
C
D
E
F
G
H
Time (ns)
0
−2047
−4095
−6143
−8191
−10239
−12287
−14335
−16383
2400
0
2×10^4
Average Waveform

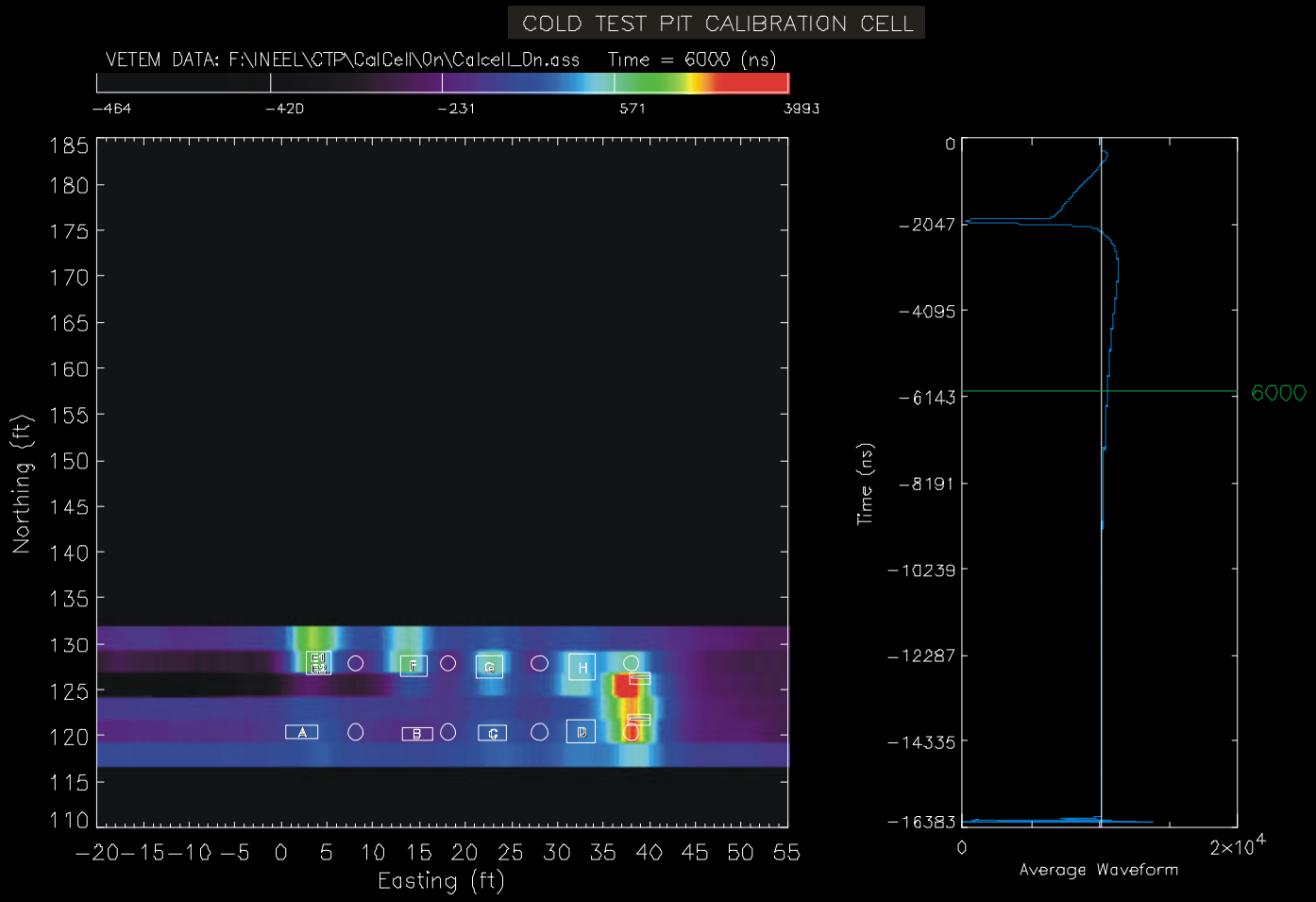

COLD TEST PIT CALIBRATION CELL
VETEM DATA: F:\INEEL\CTP\CalCell\On\CalcelI_On.ass Time = 2600 (ns)
-2123
-2072
-1730
568
1602D
Northing (ft)
Easting (ft)
Time (ns)
Average Waveform
2600
A
B
C
D
E
F
G
H

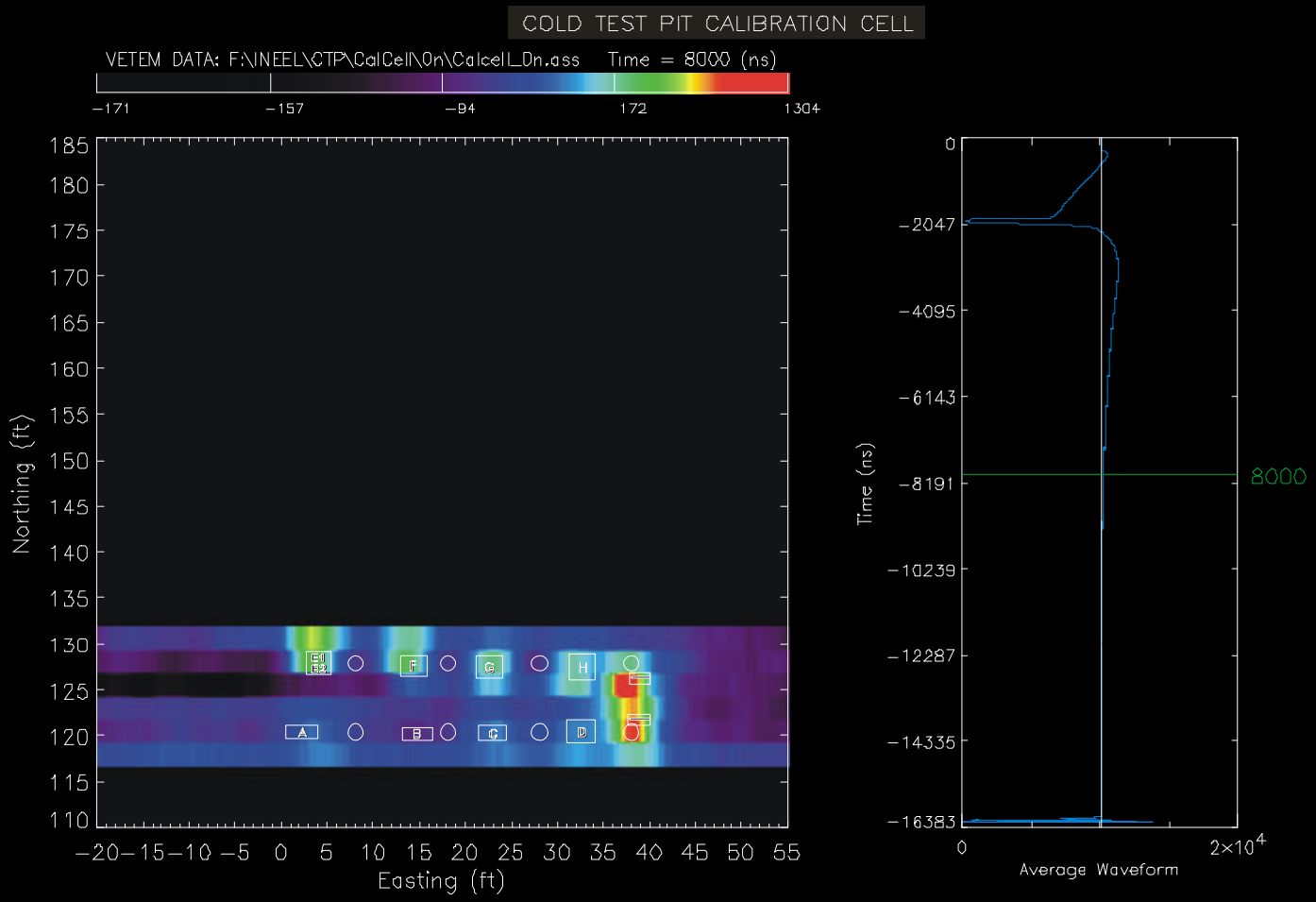

COLD TEST PIT CALIBRATION CELL
VETEM DATA: F:\INEEL\CTP\CalCell\On\CalcellOn.dss Time = 3000 (ns)
-1866
-1789
-1348
1157
15415
Northing (ft)
185
180
175
170
165
160
155
150
145
140
135
130
125
120
115
110
-20 -15 -10 -5 0 5 10 15 20 25 30 35 40 45 50 55
Easting (ft)
A
B
C
D
E
F
G
H
Time (ns)
0
-2047
-4095
-6143
-8191
-10239
-12287
-14335
-16383
3000
0
2x10^4
Average Waveform

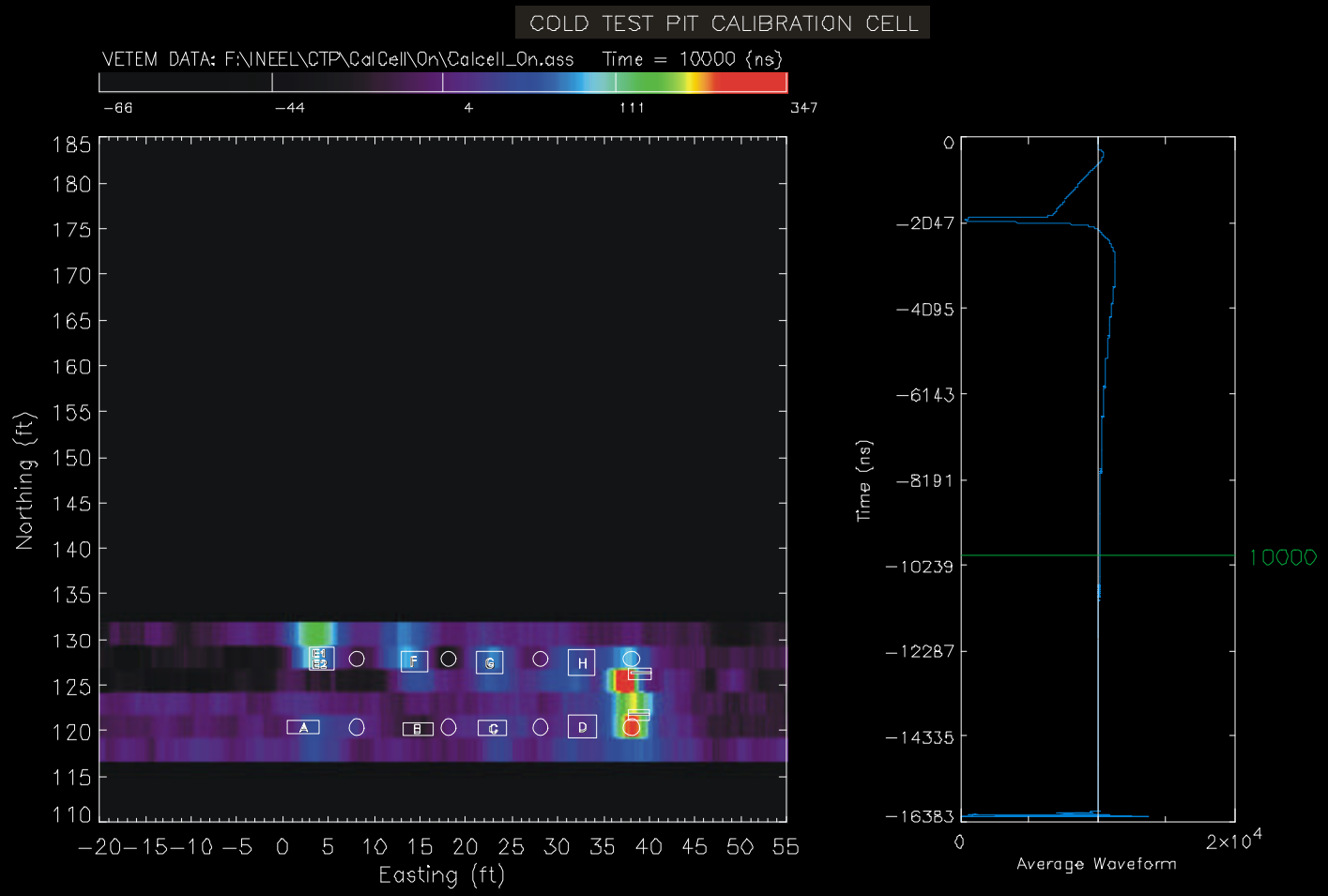

COLD TEST PIT CALIBRATION CELL
VETEM DATA: F:\INEEL\CTP\CalCell\On\CalcellOn.dss Time = 3700 (ns)
−1346
−1275
−900
1105
11824
Northing (ft)
185
180
175
170
165
160
155
150
145
140
135
130
125
120
115
110
−20 −15 −10 −5 0 5 10 15 20 25 30 35 40 45 50 55
Easting (ft)
E1
E2
F
G
H
A
B
C
D
Time (ns)
0
−2047
−4095
−6143
−8191
−10239
−12287
−14335
−16383
3700
0
2×10^4
Average Waveform


COLD TEST PIT CALIBRATION CELL
VETEM DATA: F:\INEEL\CTP\CalCell\On\CalcellOn.dss Time = 4100 (ns)
-1097
-1049
-775
795
9809
Northing (ft)
185
180
175
170
165
160
155
150
145
140
135
130
125
120
115
110
-20 -15 -10 -5 0 5 10 15 20 25 30 35 40 45 50 55
Easting (ft)
E1
E2
F
G
H
A
B
C
D
Time (ns)
0
-2047
-4095
-6143
-8191
-10239
-12287
-14335
-16383
4100
0
2×10^4
Average Waveform


COLD TEST PIT CALIBRATION CELL
VETEM DATA: F:\INEEL\CTP\CalCell\On\CalcellOn.dss Time = 5000 (ns)
-736
-705
-524
513
6485
Northing (ft)
185
180
175
170
165
160
155
150
145
140
135
130
125
120
115
110
-20 -15 -10 -5 0 5 10 15 20 25 30 35 40 45 50 55
Easting (ft)
A
B
C
D
E
F
G
H
Time (ns)
0
-2047
-4095
-6143
-8191
-10239
-12287
-14335
-16383
5000
0
2×10^4
Average Waveform


COLD TEST PIT CALIBRATION CELL
VETEM DATA: F:\INEEL\CTP\CalCell\On\CalcellOn.dss Time = 6000 (ns)
-464
-420
-231
571
3993
Northing (ft)
185
180
175
170
165
160
155
150
145
140
135
130
125
120
115
110
-20 -15 -10 -5 0 5 10 15 20 25 30 35 40 45 50 55
Easting (ft)
A
B
C
D
E
F
G
H
Time (ns)
0
-2047
-4095
-6143
-8191
-10239
-12287
-14335
-16383
6000
0
2x10^4
Average Waveform


COLD TEST PIT CALIBRATION CELL
VETEM DATA: F:\INEEL\CTP\CalCell\On\CalcellOn.dss Time = 8000 (ns)
−171
−157
−94
172
1304
Northing (ft)
185
180
175
170
165
160
155
150
145
140
135
130
125
120
115
110
−20 −15 −10 −5 0 5 10 15 20 25 30 35 40 45 50 55
Easting (ft)
A
B
C
D
E
F
G
H
Time (ns)
0
−2047
−4095
−6143
−8191
−10239
−12287
−14335
−16383
8000
0
2×10^4
Average Waveform


COLD TEST PIT CALIBRATION CELL
VETEM DATA: F:\INEEL\CTP\CalCell\On\Calcell_On.ass Time = 10000 {ns}
-66
-44
4
111
347
Northing (ft)
185
180
175
170
165
160
155
150
145
140
135
130
125
120
115
110
-20 -15 -10 -5 0 5 10 15 20 25 30 35 40 45 50 55
Easting (ft)
A
B
C
D
E1
E2
F
G
H
Time (ns)
0
-2047
-4095
-6143
-8191
-10239
-12287
-14335
-16383
10000
0
2x10^4
Average Waveform

Large Object Pit Results & Calibration Cell Results

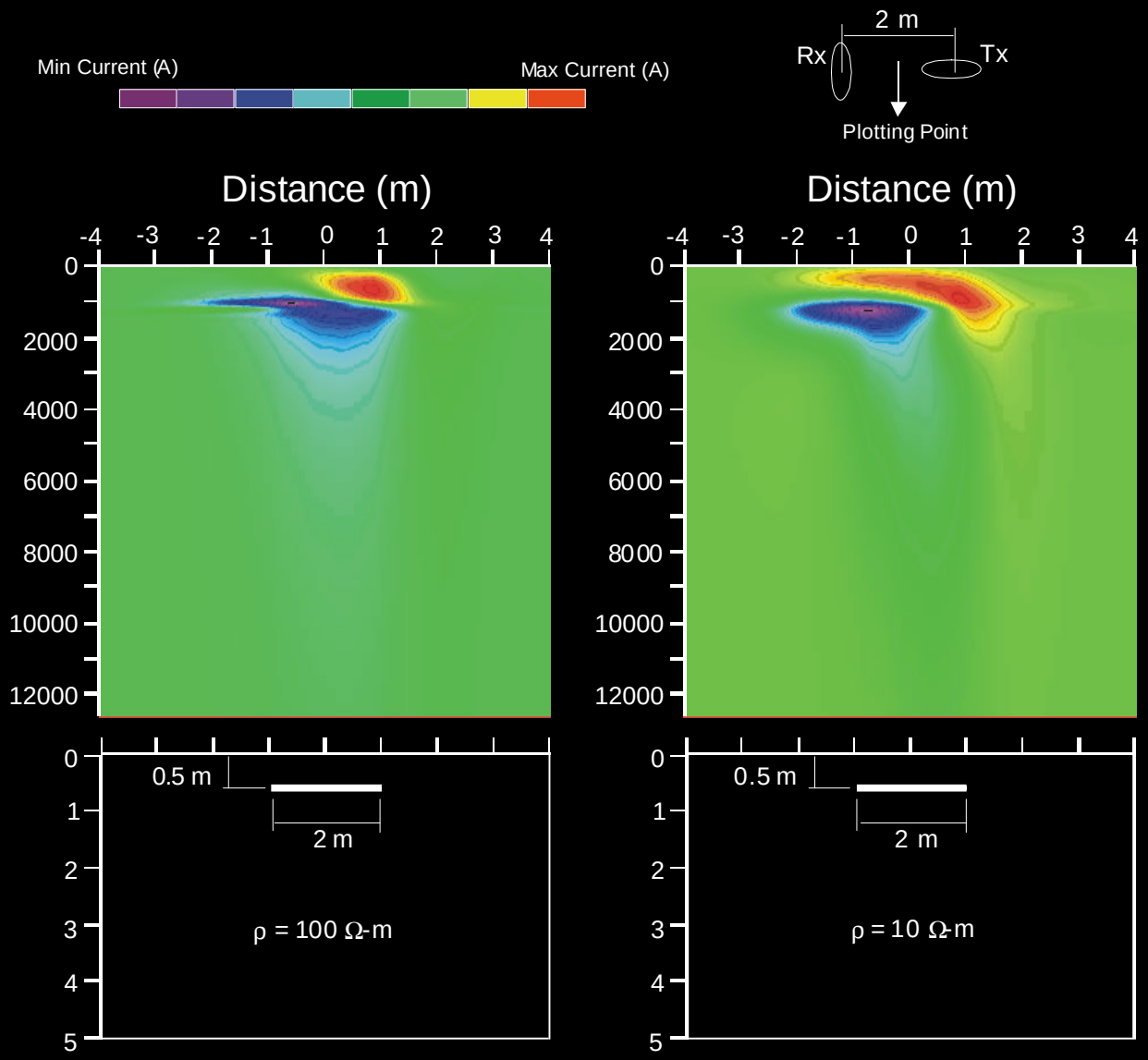
- Used both perpendicular and overlapped antennas in Large Object Pit.
- Generally good results in LOP. Some targets not seen and some uncertainty with respect to positions.
- Only overlapped antennas used in CC.
- Got returns from all targets in CC except “B” -- Salt water filled plastic drum.

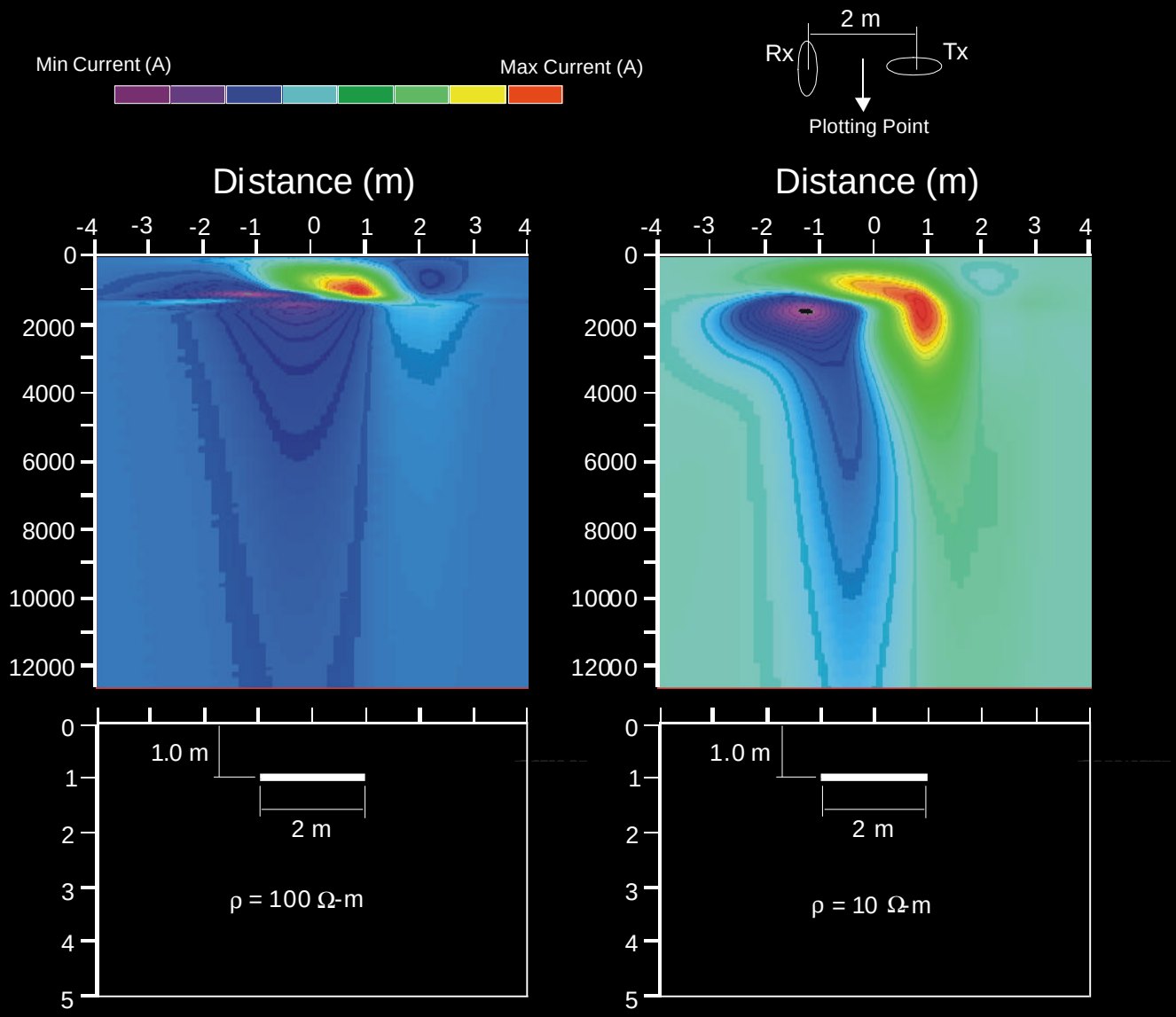
Modeling Status

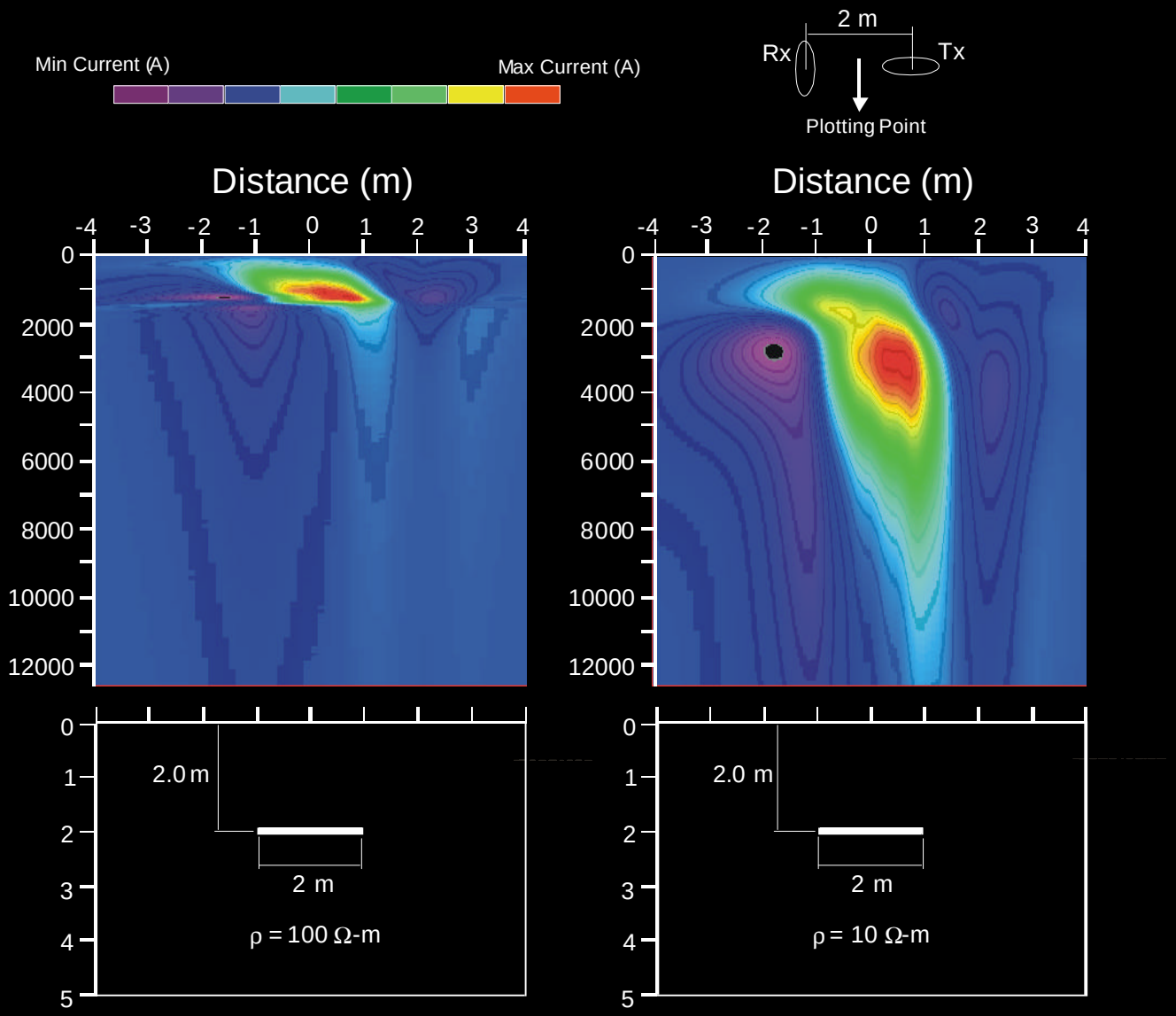
- 3-D scattering formulation forward model available:
  - One version calculates E field, another H field
  - Have run this model for several sets of parameters to study apparent target location question for perpendicular antennas
- 1-D and 2-D inverse models being developed.

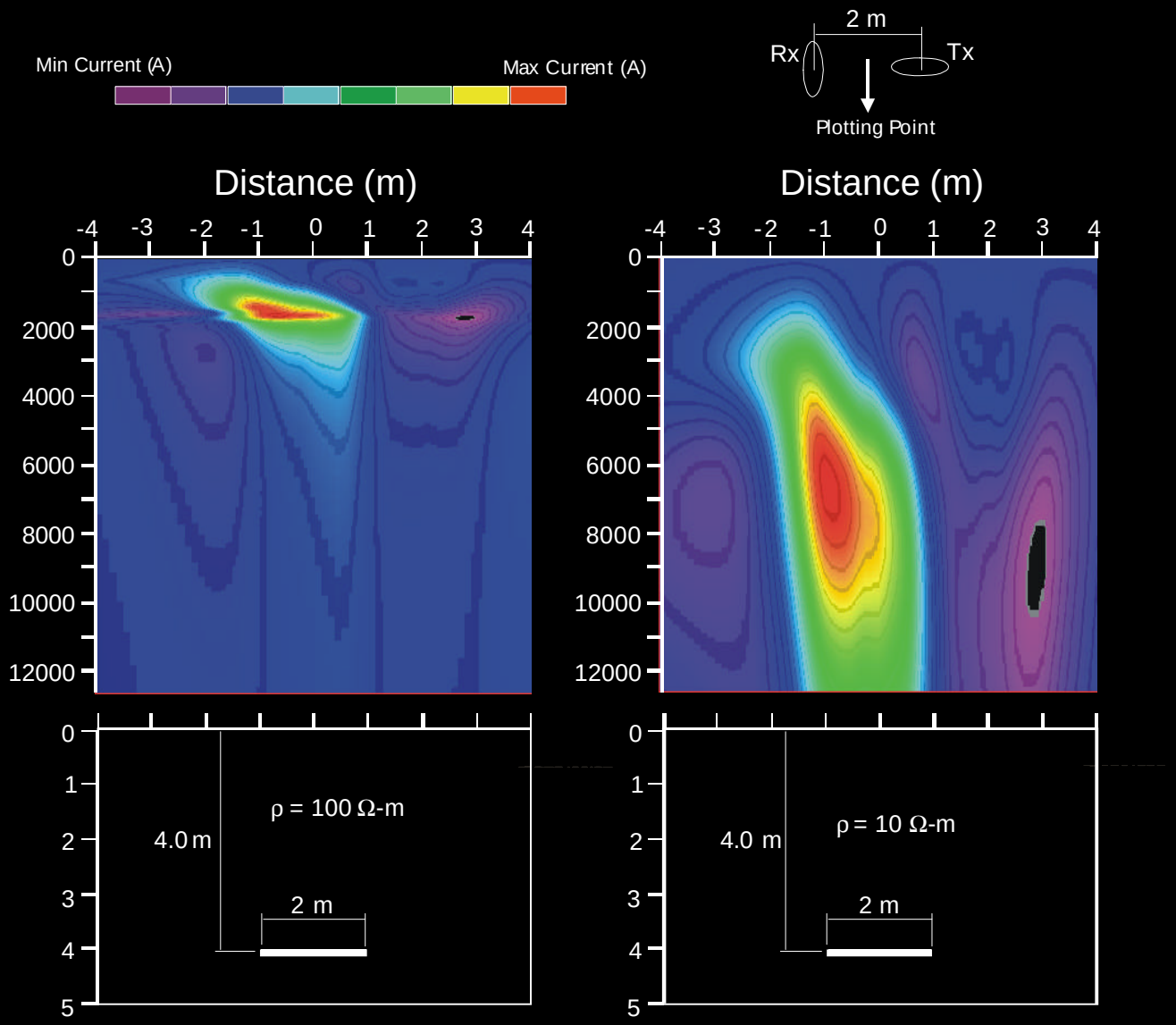
Comments on Following Simulated Profiles

- In the following 4 slides we show simulated residual (due only to scattering from buried target) profiles calculated by U. of Illinois fast 3-D forward model algorithm.
- Half-space of 100 ohm-m (left) and 10 ohm-m (right) conductivity.
- Target is 2 m by 2 m buried metal plate at depths of 0.5, 1, 2, and 4 meters.
- Assumed antennas are perpendicular at 2-m spacing.
- Tx normalized waveform assumed to turn off at 1000 ns.
- Note that apparent target location shifts slightly with time and conductivity.
- We are calculating models for other antenna configurations and polarizations.


Min Current (A)
Max Current (A)
2 m
Rx
Tx
Plotting Point
Distance (m)
Distance (m)
-4 -3 -2 -1 0 1 2 3 4
0 2000 4000 6000 8000 10000 12000
0.5 m
2 m
ρ = 100 Ω-m
ρ = 10 Ω-m
0 1 2 3 4 5


Min Current (A)
Max Current (A)
2 m
Rx
Tx
Plotting Point
Distance (m)
Distance (m)
-4 -3 -2 -1 0 1 2 3 4
0 2000 4000 6000 8000 10000 12000
1.0 m
2 m
ρ = 100 Ω-m
ρ = 10 Ω-m


Min Current (A)
Max Current (A)
2 m
Rx
Tx
Plotting Point
Distance (m)
Distance (m)
-4 -3 -2 -1 0 1 2 3 4
0 2000 4000 6000 8000 10000 12000
2.0 m
2 m
ρ = 100 Ω-m
ρ = 10 Ω-m


Min Current (A)
Max Current (A)
2 m
Rx
Tx
Plotting Point
Distance (m)
Distance (m)
-4 -3 -2 -1 0 1 2 3 4
0 2000 4000 6000 8000 10000 12000
0 1 2 3 4 5
ρ = 100 Ω-m
4.0 m
2 m
ρ = 10 Ω-m
4.0 m
2 m

What's next for VETEM?

- New receiver -- higher dynamic range
  - Linear/Log switched gain & switched bandpass
- Electric field antennas
- ATV-towed version
- Gradiometer configuration
- Data processing -- parameter extraction
- Modeling -- overlapped antennas, gradiometer, and inverse algorithms

Conclusions

- Results over Cold Test Pit have shown:
- Instrument prototype working well -- but
- Need *more* ***more*** ***more dynamic range!***
- Apparent target location questions
  - forward modeling helps
- Forward modeling code now fast enough to perform realistic simulated profiling

Acknowledgements

- We acknowledge the support of the U.S. Department of Energy Environmental Management Science Program (EMSP) and support from the Idaho National Environmental and Engineering Laboratory (INEEL) who made this work possible.